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Dollar Cost Banding

A New Algorithm for Computing Inventory Levels for Army Supply Support Activities

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Preface

Distribution Management (DM), formerly known as Velocity Management (VM), is an Army initiative to dramatically improve the performance of key logistics processes: distribution, repair, stockage determination, and financial management. This monograph describes how the then Velocity Management initiative was used to develop and implement a new algorithm for computing inventories maintained by Army supply support activities (SSAs). The new algorithm is called dollar cost banding (DCB), and it departs in important ways from the methodology that the Army had been using. First, rather than using a single qualification logic for all items, the decision of whether an item qualifies for stockage at an SSA is stratified based on item cost, size, and criticality of the demands—resulting in more items being stocked (increased breadth). Second, DCB accounts for surges and variations in demand patterns, often driven by changes in operational tempo, to compute the amount or depth of an item to stock—making it more likely a part will be available on the shelf when demands occur.

These two improvements made it possible for SSAs across the Army to dramatically improve supply performance with little additional investment in resources (either financial or mobility).

The main body of this monograph should be of interest to Army logisticians and leadership concerned with the management of spare parts inventories. More generally, those studying the implementation of supply chain improvements across large complex organizations may find this an interesting case study. The appendixes are more de-

tailed and descriptive of the algorithm and its inputs, and should be of interest to those involved in the review process used to set inventory levels at Army SSAs.

The Distribution Management approach to process improvement used in the analysis documented in this monograph was developed through research sponsored by the Deputy Chief of Staff, G-4 (Logistics). The research was conducted in RAND Arroyo Center's Military Logistics Program. RAND Arroyo Center, part of the RAND Corporation, is a federally funded research and development center sponsored by the United States Army.

RAND Arroyo Center researchers continue to extend the Distribution Management approach, which the Army has recently renamed Army Distribution Management (ADM), and to provide analytic support to the Army during the implementation.

For more information on RAND Arroyo Center, contact the Director of Operations (telephone 310-393-0411, extension 6419; FAX 310-451-6952; e-mail Marcy_Agmon@rand.org), or visit Arroyo's web site at http://www.rand.org/ard/.

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RAND routinely reviews and refines its quality assurance process and also conducts periodic external and internal reviews of the quality of its body of work. For additional details regarding the RAND quality assurance process, visit http://www.rand.org/standards/.

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Summary

When Army equipment fails, the speed with which maintenance technicians can restore it to mission-ready condition depends critically on the availability of needed spare parts. When parts are available at the maintainer's supporting supply support activity (SSA), maintainers receive their orders quickly; in contrast, parts that are unavailable at the supporting SSA might not arrive for a week or more. But despite the advantages of having parts available from the maintainer's supporting SSA, Army inventory managers determining what to stock in their deployable SSAs cannot simply base their decisions on the desire to achieve a high level of customer service by stocking as many items as possible. Instead, they must balance performance goals against the realities of limited funding and storage capacity constraints (the latter derived from the need for a highly mobile SSA). To manage this tradeoff, the Army uses an algorithm that tracks customer demands and computes which items to stock and how many of each.

However, the Army was not satisfied with the existing algorithm used to compute inventory levels for SSAs. Metrics developed under Velocity Management (VM) suggested that performance could be improved, and this was supported by evidence that Army maintainers too often found that critical parts were not on the Authorized Stockage List (ASL) of the supporting SSA, leading to long customer wait times, extended repair times, and reduced equipment availability. Part unavailability could also increase maintenance workload if maintenance technicians chose to work around a problem by remov-

ing needed parts from other pieces of inoperable equipment. When no workaround was possible, repairs could not be completed until all needed parts had arrived, thus reducing equipment readiness.

The Army's Deputy Chief of Staff, G-4 (Logistics) asked RAND Arroyo Center to develop a new algorithm for calculating inventory levels in SSAs. Arroyo logisticians applied the VM three-step methodology of Define, Measure, and Improve (D-M-I).[1] As part of this process, Arroyo developed a new stockage determination algorithm known as dollar cost banding (DCB). The idea behind the algorithm is simple: make it easier for small, inexpensive items with high-priority requisitions to be added to the ASL in sufficient depth so they are available when customer requests arrive—thus improving performance while holding down ASL storage requirements and inventory costs.

Defining the Process

To set the stage for improvement, RAND Arroyo Center researchers and other members of the VM Stockage Determination Process Improvement Team (SDPIT) walked the supply chain and inventory determination processes at several Army installations. A customer's order can be filled from one of several inventory points: (1) inventory held in the maintenance technician's shop and maintained by the parts clerk (unit-level inventory), (2) the customer's supporting SSA, (3) component repair, (4) referral from another SSA that supports other customers, (5) a regional distribution center, (6) direct vendor delivery (DVD), and (7) a backorder (when the part is not initially available from any of the SSAs or regional distribution centers, but is shipped when a replenishment from a repair source or vendor arrives). If the customer's request cannot be filled from unit-level inventory or the supporting SSA, the requirement must be passed to

[1] John Dumond et al., *Velocity Management: The Business Paradigm That Has Transformed U.S. Army Logistics.* Santa Monica, CA: RAND Corporation, MR-1108-A, 2001.

one of the other supply sources, which can be located outside the area of operations (AOR), leading to delays.

Measuring the Process

To gain a more detailed understanding of supply chain performance, the SD PIT developed a suite of metrics that address performance and resource consumption. Performance metrics, explained in the left-hand column of Table S.1, include customer service and process diagnostic metrics. Of these metrics, customer wait time (CWT) is particularly important for inventory managers because it focuses them on their customers' perspective and, implicitly, on equipment readiness. Resource metrics, also shown in the table, include several metrics associated with inventory investment, workload, and mobility.

Improving Performance

The DCB algorithm was designed specifically to address several problems associated with the Army's traditional way of calculating inventory.

More Flexible Criteria for Determining Inventory Breadth

First, DCB has made it possible to expand the breadth of deployable inventories. Traditionally, Army SSAs used a "one-size-fits-all" approach for determining whether or not to stock a particular item. While there are exceptions for low-density systems, an item not currently stocked would need nine requests over the prior review period (typically a year) to be added, while an item already stocked would need three demands to be retained.

The DCB algorithm provides greater flexibility by adjusting the criteria for determining whether an item should be added or retained according to the item's criticality, mobility impact, end item density, and dollar value. Under DCB, a small, inexpensive, but mission-

Table S.1
Performance and Resource Metrics for Inventory Management

Performance Metrics	Resource Metrics
• **Equipment readiness:** the percentage of weapon systems that are operational. • **Customer wait time (CWT):** the time from when an order is placed by the unit parts clerk until the item is issued. • **SSA fill rate:** the percentage of requests that are immediately filled from the supporting SSA—whether or not the item is on the ASL. • **Accommodation rate:** the percentage of requests for items that are on the ASL (have an RO > 0), whether or not the requested item is immediately available. • **Satisfaction rate:** the percentage of accommodated requests for which there is stock available at the time of the request.	**INVENTORY INVESTMENT** • **Dollar value of the requisition objective (RO):** the value of the maximum quantity of an item authorized to be on order or on hand at any time. • **Dollar value of the reorder point (ROP):** value of the point at which replenishment is initiated. • **Dollar value of inventory greater than the RO:** value of redistributable inventory (caused by unanticipated customer returns or when the RO is reduced when inventory levels are recomputed). **TRANSITION COSTS/SAVINGS** • **Transition costs:** the up-front investment needed to increase inventory levels of existing lines or to add new lines. • **Transition savings:** credits generated from turn-ins or draw down against future demands, resulting from a reduction in or deletion of inventory levels. **WORKLOAD** • **Workload:** the number of transactions by type required to fill customer orders and maintain inventory at proper levels. **MOBILITY** • **Number of lines:** number of unique items in the ASL with an RO > O. • **Number of cubic feet represented by the RO:** sum of the cubic feet of each item at the RO quantity. • **Number of trailers or containers:** Number of platforms used to hold inventory.

critical item might be added to inventory with only two demands per year and retained with just one per year. The algorithm also incorporates automated checks for identifying nonessential, bulky items that should not be stocked in deployable SSAs.

DCB Improves the Computation of Stock Depth

DCB also more effectively determines how many of a given item should be stocked. To do so, the new approach abandons the Army's traditional "days-of-supply" (DOS) algorithm for determining the quantity of each authorized item to stock. The main problem with the DOS method for calculating depth of inventory was the underlying assumption that demands are uniformly distributed throughout the year. Such a uniform distribution is almost never the case, due to the highly variable operational tempo (OPTEMPO) associated with Army training and deployments and the random patterns of equipment failure. The DOS approach frequently resulted in stock-outs, particularly during periods of high OPTEMPO; in other cases, capital might be tied up in a large order quantity for an expensive item. Additionally, increased workload might result because of frequent ordering of low-cost items.

The DCB approach is better able than the DOS approach to account for variations in demand and prevent stock-outs. It does this by first setting an order quantity that trades off inventory holding and ordering costs. Once the order quantity is set, an iterative simulation routine is used to arrive at the reorder point that achieves the desired CWT. Goals for CWT can be set based on unit price and criticality of the item.

In each simulation, the actual demands from the two-year review period are tracked against the daily inventory position. The simulation is initiated midway between the requisition objective (RO) and the reorder point (ROP); then each time the inventory position equals or falls below the ROP due to a demand, a replenishment order is initiated, and stocks are replenished after the replenishment lead time is computed from the data. After all the demands have been processed, the average CWT associated with the current value of the ROP is computed. A second routine adjusts the ROP,

and the simulation is repeated until the CWT goal is achieved. To reach the CWT goal, the algorithm establishes a tradeoff between safety level, order quantity, and backorder time if the item is not available from the ASL (which affects CWT).

Automated Checks to Reduce Workload

The new DCB methodology also saves time by automating many of the decision rules typically used by local supply managers. The algorithm automatically identifies certain nomenclatures and federal supply classes (FSCs) that should not be stocked and automates the process for identifying low-density and other items (e.g., aviation and missile) that would normally not qualify for inventory under the "9 demands to add and 3 demands to retain" criterion (hereafter, 9/3) but for which policy exceptions to add with three demands and retain with just one demand have existed. This automation reduces the time and workload necessary to conduct ASL reviews while improving their effectiveness.

Improvements Under Dollar Cost Banding

DCB has been used successfully to conduct ASL reviews in divisional SSAs, nondivisional tactical SSAs, and nontactical SSAs. DCB was first used to conduct ASL reviews in the 101st Air Assault Division and led to a significant increase in the breadth of inventory, despite the tight mobility constraints under which the SSAs operate. For example, after the first ASL review with DCB in 1998, the number of unique parts stocked in the forward support battalions (FSBs) doubled or tripled, while those in the main support battalion (MSB) more than doubled. Much of the increase resulted from adding items that cost less than $100 and had experienced high-priority demands.

The use of DCB in the 3rd Infantry Division led to an expansion in the breadth and depth of certain items while reducing the overall inventory investment and ASL mobility requirements. The initial ASL review under DCB resulted in a 33 percent increase in the number of stocked items (i.e., unique items stocked, referred to as

"lines"), with the largest increases occurring in the FSBs and the aviation support battalion (ASB). The RO value of the ASLs was reduced from $58.2 million to $53.5 million. The total cube of the parts in the ASL was reduced and the number of trailers in the MSB was reduced, thus improving mobility. A second ASL review using DCB, conducted in September 2000, resulted in further improvements. Fill, satisfaction, and accommodation rates all rose. As a result of improved ASL performance, CWT was reduced.

The use of DCB in ASL reviews has also led to improved inventory performance at the Army's Armor Center and School at Fort Knox. As home to the Army's tank training, Fort Knox supports a high OPTEMPO similar to that of deployed units. The DCB recommendations at Fort Knox resulted in a net decrease in inventory value of $1.3 million, while the number of unique parts stocked in the warehouse almost doubled to 4,572. Unlike the deployable units such as those found in the 101st Air Assault Division and 3rd Infantry Division, Fort Knox operates its SSA out of a nondeployable fixed warehouse with considerably more storage space. With the application of DCB, the SSA fill rate at Fort Knox improved from 41 percent to 63 percent, mostly due to higher accommodation rates. As a result, the median CWT for high-priority demands collapsed from 2–3 days to the same or next day.

Improved local fill rates and reduced CWT led to an increase in the operational availability of the M1A1 tank fleet at Fort Knox. One of the reasons for this improvement was an increase in the percentage of repair jobs for which all the required parts were available from the ASL. When all parts required for a job are stocked in the ASL, repairs can be completed more quickly because no parts need to be requisitioned from off post. Overall, the average repair time for M1A1 tanks at Fort Knox decreased from 12.4 days to 8.8 days, a 29 percent decrease.

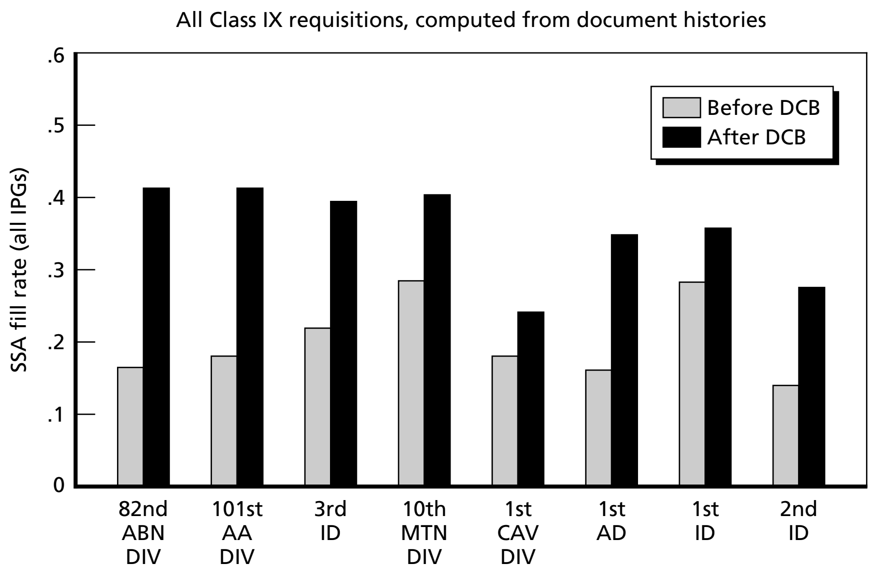
Inventory Performance Improvements for SSAs Across the Army

The DCB logic has been incorporated into the Integrated Logistics Analysis Program (ILAP). At the same time, RAND Arroyo Center has continued its research to improve the DCB algorithm. The use of DCB has also been made part of Army policy. In 2000, DCB was made an approved policy option for units conducting ASL reviews; while in 2002, the use of DCB was made mandatory for ASL reviews.

Figure S.1 shows the ASL fill rates for eight active Army divisions before and after the use of DCB for an ASL review.

The best performance is in the XVIII Corps divisions (the four leftmost divisions in the figure), which were the first to use DCB in ASL reviews. Units that have not shown as strong an improvement

Figure S.1
Fill Rates for Divisions Before and After ASL Reviews with DCB



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have not been able to fully leverage the recommendations from DCB due to budget or other constraints or have conducted fewer ASL reviews with DCB.

Continuous Improvement

The final step of any process improvement, after propagating it across the organization, is always one of continuous improvement. The experience to date has suggested two major areas in which DCB can be improved:

- **First, the recommendations of DCB need to be better linked to weapon system readiness.** To better tailor the ASL to support readiness, RAND Arroyo Center is linking the DCB logic with data on requisitions for parts needed to complete maintenance jobs to return inoperable equipment to mission-ready status. Such data are available through the Equipment Downtime Analyzer (EDA),[2] which provides a systemwide view of how much each process and organization contributes to equipment downtime. Arroyo is seeking to improve upon the existing logic of how to identify a "critical" item, then better focus inventory investment and mobility resources on readiness drivers.
- **Second, inventory decisions for Army Materiel Command (AMC)-managed items need to be coordinated across echelons under SSF.** Under Single Stock Fund Milestone III (SSF MS III), the inventory in tactical SSAs converted to Army Working Capital Fund (AWCF) ownership. This shift will potentially reduce some of the financial barriers to improving ASLs. Arroyo is considering additions to the DCB logic to address resource allocation under the new funding environment.

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[2] Eric Peltz et al., *Diagnosing the Army's Equipment Readiness: The Equipment Downtime Analyzer*, Santa Monica, CA: RAND Corporation, MR-1481-A, 2002.

Acknowledgments

This monograph records the achievements of a wide-ranging effort and reflects the hard work of individuals from many organizations who contributed to the Army's Velocity Management initiative, the Stockage Determination Process Improvement Team (SD PIT), and unit Site Improvement Teams (SITs) that led to the implementation of DCB as a viable ASL review methodology across the Army. This represents a large change for the Army, and it would be impossible to acknowledge all those who contributed.

However, we begin by gratefully acknowledging our debt to current and former leaders and logisticians of the SD PIT. Most notable for his eloquent arguments in favor of bringing change to the ASL review process is the late MG (ret.) Jim Wright. MG Hawthorne L. Proctor also led the SD PIT and pushed to expand the use of DCB across the Army as quickly as possible. The tireless efforts of Mr. Tom Edwards, Deputy to the Commanding General of CASCOM, were invaluable to the successful implementation of DCB. LTG (ret.) Charles Mahan, as Army G-4, and MG Daniel Mongeon, as FORSCOM G-4, were instrumental in pushing for both implementation and policy changes. Special thanks are due to MG Mitch Stevenson, G-3 Army Materiel Command, and MG Ross Thompson, Commander TACOM, for their assistance and feedback.

Both the Velocity Management team at CASCOM and the Army G-4 staff have been important contributors to this effort. We would like to thank COL Joe Walden, LTC (ret.) Chris Schieffer, LTC (ret.) Tony Fuller, CW5 Leo Gibson, CW5 (ret.) John Lowes,

CW4 Matt Anderson, CW4 (ret.) Ramon Navarro, and all the members of these organizations and others that assisted this effort through their participation in the SD PIT.

We gratefully acknowledge the contribution of CW4 Steve Fergus, CW4 (ret.) Ken Deans, Ms. Sandra Simms, and Mr. Russ Reingeisen. From the beginning of the DCB effort, they provided invaluable insight into the ASL review analysis process and the SARSS operation. They also provided details and recommendations that were critical to the DCB development. The other folks in the units who participated with us in the ASL reviews and really made this happen are, simply put, too numerous to acknowledge individually. But we would like to provide a special heartfelt thank you to those who put their trust in us and acted as messengers.

We also wish to acknowledge the research contributions of our RAND Arroyo Center colleagues, including John Dumond, Eric Peltz, Rick Eden, Thomas Held, and Pat Boren. Pamela Thompson helped to manage the document through many revisions, and Nikki Shacklett improved it in many ways with her expert editorial skills.

Glossary

1st AD	1st Armored Division
1st CAV	1st Cavalry Division
1st ID	1st Infantry Division
10th MTN	10th Mountain Division
101st AA	101st Airborne Division (Air Assault)
2nd ID	2nd Infantry Division
3rd ID	3rd Infantry Division (Mech)
82nd ABN	82nd Airborne Division
AAC	Acquisition Advice Code
ABF	Availability Balance File
AMC	Army Materiel Command
ASB	Aviation Support Battalion
ASL	Authorized Stockage List
AVIM	Aviation Intermediate Maintenance
AVN	Aviation
AWCF	Army Working Capital Fund
CASCOM	Combined Army Support Command
CTASC	Corps/Theater Automatic Data Processing Service Center

CWT	Customer Wait Time
DC	Distribution Center
DCB	Dollar Cost Banding
DISOS	Due in source of supply
DLA	Defense Logistics Agency
D-M-I	Define, Measure, Improve
DODAAC	Department of Defense Automatic Address Code
DOS	Days of Supply
DVD	Direct Vendor Delivery
EDA	Equipment Downtime Analyzer
EOQ	Economic Order Quantity
FED LOG	Federal Logistics Data
FORSCOM	Forces Command
FSB	Forward Support Battalion
FSC	Federal Supply Class
ILAP	Integrated Logistics Analysis Program
IP	Inventory position
IPG	Issue Priority Group
MATCAT	Materiel Category
MR	Maintenance Repair
MSB	Main Support Battalion
NIIN	National Item Identification Number
NTC	National Training Center
OCONUS	Outside the Continental United States
OH	On hand
OMA	Operations and Maintenance Account

OOU	Order of use
OPTEMPO	Operational tempo
OR	Operational readiness
PLL	Prescribed Load List
RCT	Repair Cycle Time
RIC	Routing Identifier Code
RLT	Replenishment lead time
RO	Requisition Objective
ROP	Reorder Point
SARSS	Standard Army Retail Supply System
SD PIT	Stockage Determination Process Improvement Team
SIT	Site Improvement Team
SL	Safety level
SOS	Source of supply
SSA	Supply Support Activity
SSF	Single Stock Fund
TACOM	Tank and Automotive Command
TRADOC	U.S. Army Training and Doctrine Command
VM	Velocity Management
YEB	Document identifier code used for transactions that update the inventory levels on the ABF

CHAPTER ONE

Introduction

When Army equipment fails, the speed with which maintainers can restore it to mission-ready condition depends critically on the availability of needed spare parts. When parts are available at the supporting supply support activity (SSA), customers can usually receive their orders quickly; in contrast, parts that are unavailable at the SSA might not arrive for a week or more. But despite the advantages of having parts available from the supporting SSA, Army inventory managers determining what to stock in their deployable SSAs cannot simply base their decisions on the desire to achieve a high level of customer service by stocking as many items as possible. Instead, they must balance performance goals against the realities of budget and storage capacity constraints. To manage this tradeoff, the Army uses an algorithm that computes which items and how many of each to stock based upon customer demands.

However, the Army was not satisfied with the existing algorithm used to compute inventory levels for SSAs. Too often, Army maintainers found that critical parts were either not in stock or not on the Authorized Stockage List (ASL) of the supporting SSA, leading to long customer wait times, extended repair times, and reduced equipment availability. In many cases, maintainers who were unable to wait any longer for parts to maintain readiness had to make extra efforts to work around part availability problems, such as by taking parts from another piece of inoperable equipment. When no workaround was possible, repairs would have to wait until all needed parts had arrived, thus reducing equipment readiness.

It became apparent that the Army's traditional algorithm was not well suited to the kinds of demand patterns generated by the variable operational tempo (OPTEMPO) of Army units at brigade level. Moreover, developments in inventory management suggested that better performance could be achieved. The Army's G-4 (Deputy Chief of Staff) therefore asked RAND Arroyo Center to develop a new algorithm for calculating inventory levels in SSAs. Arroyo logisticians were already engaged in several "Velocity Management" (VM) projects, with the goal of making the Army's supply system faster, better, and cheaper.[1]

Arroyo researchers applied VM's three-step process improvement methodology of Define, Measure, and Improve (D-M-I) to the Army's inventory management process. The first step, "Define," identifies the customers of the process and specifies what they need in terms of outputs. The inputs to the process are also defined, and the process itself is mapped by segment. The next step, "Measure," aims to understand how well the process has performed in terms of time,

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[1] To learn more about the Army Velocity Management program, please see John Dumond et al., *Velocity Management: The Business Paradigm That Has Transformed U.S. Army Logistics*, Santa Monica, CA: RAND Corporation, MR-1108-A, 2001; John Dumond et al., *Velocity Management: An Approach for Improving the Responsiveness and Efficiency of Army Logistics Processes*, Santa Monica, CA: RAND Corporation, DB-126-1-1, 1995; and Mark Y.D. Wang, *Accelerated Logistics: Streamlining the Army's Supply Chain*, Santa Monica, CA: RAND Corporation, MR-1140-A, 2000. For a concise discussion of the development of the DCB algorithm, see *Improved Inventory Policy Contributes to Equipment Readiness*, Santa Monica, CA: RAND Corporation, RB-3026-A, 2001.

Initial VM research was directed toward improving the order fulfillment process from wholesale distribution centers. For more detailed discussions of the Army's improvement of the order fulfillment process, see Wang, cited above, and Ken Girardini et al., *Establishing a Baseline and Reporting Performance for the Order and Ship Process*, Santa Monica, CA: RAND Corporation, DB-173-A, 1996.

The Velocity Management process was also subsequently applied to the Army's repair and financial management processes. For information on the financial management processes, please see Ellen M. Pint et al., *Right Price, Fair Credit: Criteria to Improve Financial Incentives for Army Logistics Decisions*, Santa Monica, CA: RAND Corporation, MR-1150-A, 2002; Marygail K. Brauner et al., *Dollars and Sense: A Process Improvement Approach to Logistics Financial Management*, Santa Monica, CA: RAND Corporation, MR-1131-A, 2000; and Marygail K. Brauner et al., *Evaluating Five Proposed Price and Credit Policies for the Army*, Santa Monica, CA: RAND Corporation, DB-291-A, 2000.

quality, and cost. Metrics are developed to support measurement in these areas. The third step, "Improve," capitalizes on the increased expertise developed during the first two steps to articulate realistic but challenging goals for improvement and identify and implement process improvements to achieve the goals.

The application of the D-M-I method resulted in the development of a new stockage determination algorithm known as dollar cost banding (DCB). The idea behind the algorithm is simple: make it easier for small inexpensive items with high-priority requisitions to be added to the ASL in the appropriate depth so they are available when customer requests arrive—thus improving performance while holding down deployment requirements and inventory costs. The DCB algorithm has produced immediate and significant gains in performance at little or no additional inventory cost and without sacrificing mobility. Improved inventory performance means that customers spend less time waiting for parts and working around part availability problems. As a result, repairs can be completed more quickly, which translates into higher equipment readiness rates or, in some cases, similar rates with a reduced maintenance burden.

Army SSAs that have used DCB to conduct ASL reviews have seen improved performance. This has occurred across all different types of SSAs, including main, forward, nondivisional, and aviation support battalions, and across all types of units, including armor, light, and nondivisional. Based upon the dramatic effectiveness of DCB demonstrated at a few pilot sites, the Army G-4 approved it as a policy option for determining inventory requirements at retail supply points Armywide on October 12, 2000. After the use of DCB across many more sites further validated the new algorithm as better than the Army's existing inventory algorithm, the Army G-4 changed the policy on November 4, 2002 to make the use of DCB mandatory for ASL reviews. The Army has 47 divisional SSAs, of which 43 have now done at least one ASL review using DCB that resulted in signifi-

cant changes consistent with the underlying DCB logic.[2] Also, almost half the nondivisional SSAs and some installation SSAs have completed at least one ASL review using DCB.

Organization of Report and Intended Audience

This report describes DCB and the improved performance it has made possible. The main body of the report should be of greatest interest to Army logisticians and the leadership involved in the management of spare parts inventories. These chapters will also be of interest to those interested in the implementation of supply chain improvements across large complex organizations. The remainder of this report is organized in four chapters. Chapter Two explains the need to improve the performance of spare parts inventories and describes some metrics that can be used to measure and track progress. Chapter Three discusses the development and underlying logic of the algorithm, while Chapter Four focuses on the implementation of DCB and the impact it has had. Chapter Five describes directions for future improvement.

More technical audiences, especially those who have experience with the ASL review process used to set inventory levels at Army SSAs, are referred to the Appendixes, which describe the algorithm itself and its inputs.

[2] The degree to which performance improves is a function of financial and mobility constraints and the degree to which local supply managers accept the recommendations of the algorithm.

CHAPTER TWO

Why Improve the Effectiveness of Army Inventories?

For each SSA, the Army's inventory management process determines both the breadth of inventory (Is an item stocked?) and its depth (How many of each item should be stocked?). These two aspects of stock determination define what level of investment will be required and what level of performance will be achieved, and how much materiel will have to be deployed and moved around a battlefield. The Army wanted to improve the effectiveness of the stock determination process, in terms of both performance and efficiency.

To set the stage for improvements, RAND Arroyo Center researchers and Army supply personnel first defined the inventory management process and developed metrics to help understand current levels of performance and to track progress.

Defining the Process

During the first—or "Define"—step in the process, Arroyo researchers and other members of the Stockage Determination Performance Improvement Team[1] (SD PIT) visited several Army installations to

[1] The Stockage Determination Process Improvement Team (SD PIT) is composed of functional experts representing all the segments of the inventory management process as well as Army and RAND Arroyo Center analysts. The members of the SD PIT included the personnel from the office of the Army Deputy Chief of Staff (DCS), G-4, Department of the Army (DA), the Combined Arms Support Command (CASCOM), Army Materiel Command (AMC), the U.S. Army Quartermaster Center and School, Forces Command

define or map the inventory management process. They walked through the process to understand its role in the overall context of the Army's supply chain. As part of this step, the team identified the various inventory points along the supply chain that could provide materiel used to fill a customer's request (Figure 2.1). The "customer" refers to the unit parts clerk who orders parts for the unit's maintenance technicians or equipment operators.

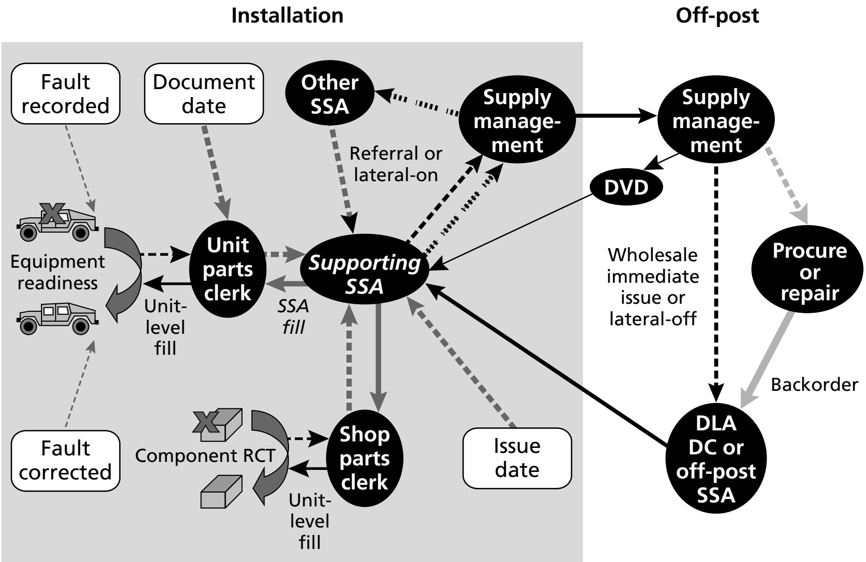
As shown, a part request can be filled from one of several sources:

- **Unit-level fill** occurs when the part required by the maintenance technician or operator is issued from inventory held and maintained by the parts clerk (unit-level inventory). This is an over-the-counter transaction and no electronic record is made of the request (though an electronic record will be made for the replenishment of unit-level inventories).
- **SSA fill** occurs when the part required by the maintenance technician or operator is issued from inventory held at the supporting SSA. In this case, the request is passed to the unit parts clerk, who enters the request into the unit-level supply information system and passes it up to the supporting SSA, which then fills the request immediately from on-hand assets at the SSA.

The unit parts clerk passes the request to the SSA. If the SSA is unable to issue the requested item from on-hand assets, the SSA passes a requisition for the desired part further up the supply chain. When the part becomes available from one of the supply sources listed below, the part is delivered to the supporting SSA, which then issues it to the unit parts clerk. Often the part is immediately avail-

(FORSCOM), and the RAND Corporation. The PIT was charged with walking through the inventory management process to establish common, detailed definitions; developing process metrics and performance reports; conducting analyses of current performance; and recommending process changes designed to improve performance. The work of the SD PIT is supplemented by that of site improvement teams (SITs) at the installations. A SIT is composed of local technical experts and managers.

Figure 2.1
The Supply Chain Can Fill a Parts Request from Many Different Sources



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able from on-hand inventory at multiple supply sources and business rules determine which source will fill the request.

- **A maintenance fill** occurs when the part requested by the customer is available after being repaired by an Army maintenance activity aligned with the supporting SSA and returned to the supporting SSA in serviceable condition (e.g., when a repaired component is returned to the SSA and then immediately issued to fill an outstanding customer request instead of being placed back on the shelf).
- **A referral or lateral-on fill** occurs when the part requested by the customer is filled by an SSA in the same geographical area (typically on the same installation) but other than the supporting SSA.
- **A wholesale immediate issue or lateral-off** occurs when the part requested by the customer is filled from immediately re-

leased on-hand assets at a distribution center or an SSA not in the same geographic area.

- **Direct vendor delivery (DVD)** occurs when the part requested by the customer is shipped directly from the vendor to the customer's supporting SSA, typically through a prearranged Electronic Data Interchange (EDI) link between the national inventory control point and the vendor.
- **Wholesale backorder** occurs when the part requested by the customer is not available as releasable on-hand inventory in the supply system. Typically the request will not be filled until a depot (or other maintenance activity not aligned with the supporting SSA) repair is completed or vendor delivery to a distribution center occurs.

In terms of the time necessary to fill a request, the most advantageous supply source is a unit-level fill, but the unit's ability to carry inventory is typically severely constrained. The next most advantageous supply source is SSA fill. If an SSA fill is not possible, the requirement must be passed on to one of the other supply sources, which can lead to lengthy delays, particularly if the item is not on hand or otherwise unavailable for immediate release.

Metrics to Identify Areas for Improvement

The next step in the D-M-I methodology focuses on measurement. To gain a more detailed understanding of supply chain performance, the SD PIT developed a suite of metrics to address the dimensions of time, quality, and cost. Inventory management metrics fall into two categories: performance metrics and resource metrics. Both types of metrics are needed to balance the desire to provide responsive support to customers (the time and quality dimensions of performance) with investments in inventory and the use of other resources, such as transportation (cost dimension of performance).

Table 2.1
Performance Metrics for Inventory Management

- **Equipment readiness.** The percentage of weapon systems that are operational.
- **Customer wait time (CWT).** The time from when an order is placed by the unit parts clerk until the item is issued.
- **SSA fill rate.** The percentage of requests that are immediately filled from the supporting SSA—whether or not the item is on the ASL.
- **Accommodation rate.** The percentage of requisitions for items that are on the ASL, whether or not the requested item is immediately available. For such items, the maximum number of the item that should be stocked (known as the requisition objective or RO) > 0.
- **Satisfaction rate.** The percentage of accommodated requests for which there is stock available at the time of the request.[a]

[a] In this report, requests for which part of the quantity requested is filled (e.g., the customer requests two items but there is only one on the shelf) are counted as satisfied. While this is contrary to the Army definition and current metrics, it is done to maintain consistency with the earliest data used in the report and to track trends over time without definitional changes that could create discontinuities in the metrics.

Performance metrics for inventory management are shown in Table 2.1. Equipment readiness is the most critical metric, but alone it is not a good indicator of SSA performance, since many other factors (e.g., failure rates, OPTEMPO, and the availability of maintenance technicians to perform the required repairs) beyond what is stocked in the SSA can affect equipment readiness. Customer wait time (CWT) is particularly important because it focuses inventory managers on their customers' perspective and, implicitly, on equipment readiness by isolating supply performance from the other factors that affect equipment readiness. CWT measures the time from when an order is placed by the unit parts clerk until the item is issued.[2] Fill

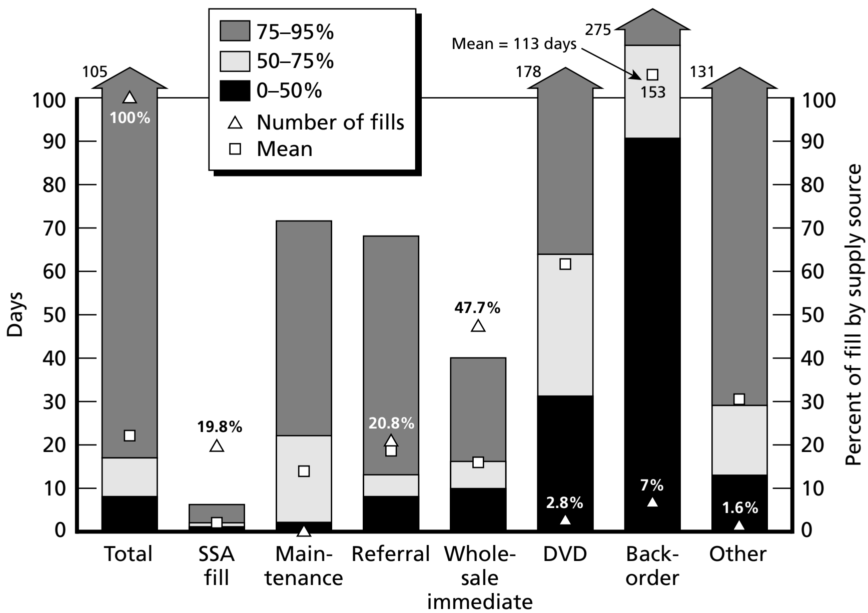
[2] As currently measured, CWT measures all segments of the supply process for which data are available. No records are kept concerning the time at which a fault is initially recorded by maintenance until the part request reaches the parts clerk. And, as noted above, no records are available concerning transactions involving local shop inventories (PLL, shop stock, and bench stock). After the item has been receipted and issued by the SSA, no data are available concerning the time it takes for the parts clerk to get the part and then get it to the maintainer for equipment repair.

rate, accommodation, and satisfaction rate are also useful metrics for tracking performance.

Figure 2.2 depicts overall CWT (on the far left) and then by source of fill across the horizontal axis. The sources of fill on the horizontal axis correlate with the sources illustrated in Figure 2.1 (except, as noted above, CWT for unit-level fill is not tracked). The data is for the 82nd Airborne Division in May 1999, four months before the application of DCB.

In the figure, higher column segments imply longer and more variable times that the customer must wait for the requested part. The three-segment column indicates the number of days needed to fill 50 percent of requests (top of the bottom black segment), 75 percent of requests (top of the middle, light gray segment), and 95 percent of requests (top of the dark gray segment). The small square on

Figure 2.2
Customer Wait Time (CWT) by Source of Fill



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each column shows the mean CWT for that source of fill, while the triangular marker indicates the percentage of requests filled by each source, read from the right-hand vertical axis. Total CWT is the aggregation of CWT performance from each of the sources of fill and so has a triangular marker at 100 percent.

The relative heights of the CWT columns are indicative of the advantages of filling a customer's part request from the supporting SSA. For the 82nd Airborne, mean CWT was only 1.8 days for SSA fills, compared to, for example, 18 days for referrals and 113 days for backorders. CWT for ASL fills was also much less variable, as indicated by the 95th percentile at 4 days as compared to 275 days for backorders. Thus, customers whose orders were filled by their supporting SSA could be fairly confident of receiving their orders within a short time, whereas those whose requirements were passed on by the SSA to other sources would wait longer; perhaps as important, the amount of wait time could be highly uncertain.

Despite the advantages of SSA fills, fewer than 20 percent of customer requests were filled from this source. As a result, the vast majority of customer requests were filled from supply sources above the supporting SSA in the supply chain, with longer and more variable response times resulting in significant delays. Total CWT for the 82nd Airborne Division was lengthy and highly variable, reflecting the longer response times associated with these other sources of fill. Improving the percentage of customer requests from SSA fill was one of the division's most powerful levers for improving CWT.

The SSA fill rate depends on both the breadth and depth of the inventory, that is, whether the needed item is stocked and, if it is, whether it is available or out of stock when the customer requests it.[3] Breadth and depth can be measured, respectively, by accommodation and satisfaction rates (see Table 2.1), which are useful diagnostic metrics for understanding how to improve an ASL.

[3] The SSA fill rate is also a function of retention levels (RLs), but this research will focus only on the breadth and depth of the authorized inventory levels.

While the metrics just discussed provide a means of measuring and diagnosing performance and tracking improvement, the ability of units to do well in terms of performance metrics is constrained by the number and kind of resources available—financial, personnel, time, etc. Resource metrics for inventory management are shown in Table 2.2.

The financial constraints involved in transitioning the SSA from an existing stock position to another were apparent to the SD PIT during the visits to Army installations. This transition typically involves returning some items and purchasing others. For example, an

Table 2.2
Resource Metrics for Inventory Management

- **Inventory investment.** The most common metric of inventory investment is the dollar value of the *requisition objective* (RO). The RO for a stocked item is the maximum number of the item that should be on hand. Other metrics of inventory investment are the dollar value of the *reorder point* (ROP, the inventory level at which replenishment is initiated) and dollar value of *inventory greater than the RO* (inventory above the RO can occur in the event of unanticipated customer returns or when RO levels are reduced).

- **Transition costs/savings.** Transition costs involve the up-front investment needed to increase inventory levels of existing lines or to add new lines. Transition savings include credit from turn-ins generated by reductions in the inventory levels of existing lines or by the elimination of existing lines. Savings can come, alternatively, in the form of "draw down" against future demands by retaining inventory above the RO and then not replenishing (or replenishing to a lower level of inventory).

- **Workload.** Workload refers to the level of activity required to fill customer orders and maintain inventory at the proper levels. One measure of workload is the number of receipts and issues processed by the SSA.

- **Mobility.** Mobility metrics concern inventory issues affecting a unit's deployment and battlefield movement capabilities. For example, the *number of lines* carried in inventory will have an effect on the number of storage locations required in the warehouse. Another mobility metric is the *number of cubic feet represented by the RO*, which is calculated by summing the cubic feet of each item as if held at the RO quantity. A third metric is the *number of trailers or containers* used to store inventory. The third metric is a direct indication of mobility requirements.[a]

[a] Units typically have a fixed number of trucks to move inventory and trailers to carry it. They tend to have somewhat more flexibility in the number of containers, but they generally do not have more than they can carry with organic lift assets.

algorithm might recommend a different set of parts with a lower total requisition objective (RO) value and improved performance. However, even though the total RO value will be less, the transition to different parts can require significant investment. The supply managers often lack sufficient resources to purchase every item they might want to stock at a given time. Moving from one stock posture to a more desirable one is a continuous improvement process, which must usually be accomplished in stages as resources become available.

A key resource metric is the dollar value of the RO, the best indication of total inventory investment. But additional metrics are needed to accurately reflect the transition costs associated with changes in inventory, workload to operate the SSA's warehouse, and the mobility requirements.

The issue for the Army, then, was how the performance of Army inventories could be improved within resource constraints. This issue will be discussed in the next chapter.

CHAPTER THREE

Developing an Improved Inventory Algorithm

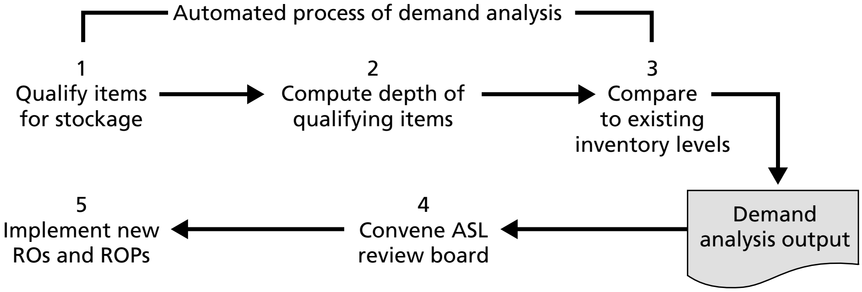
The Army's desire to improve inventory performance led to the development of an improved algorithm for setting inventory levels. The dollar cost banding algorithm has made it possible to expand both the breadth and depth of deployable inventories, while holding down costs and not exceeding lift capacity. As will be shown in this chapter, the new algorithm was designed specifically to address several problems associated with the Army's traditional way of calculating inventory.

The Process of Qualifying Items for Inventory

To understand the dollar cost banding method, we need first to take a closer look at the Army's stockage determination process, i.e., the means through which items are added to or eliminated from inventory and through which inventory levels are set. The Army's stockage determination process consists of five steps, as illustrated in Figure 3.1.

- **Step 1: Qualify items for stockage.** The first automated step of the process is to determine the potential breadth of the ASL, that is, which items qualify to be stocked.
- **Step 2: Compute the depth of qualified items.** The next step is to compute the appropriate depth of the items that have qualified for stockage. The inventory levels (i.e., the RO and ROP) determine the depth of stockage.

Figure 3.1
Five Steps of the Army's Traditional Stockage Determination Process



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- **Step 3: Compare recommendations to existing inventory levels.** The third automated step organizes recommendations into four categories:
  - **adds:** items to be added to the ASL (for which an RO > 0 will be set) that do not currently have a positive RO;
  - **increases:** items with current ROs that are being increased (new RO > the current RO);
  - **deletes:** items with a current positive RO that will no longer have an RO (new RO = 0); and
  - **decreases:** items with a currently positive RO that will have a decreased but still positive RO (new RO < current RO).
- **Step 4: Convene ASL review board.** In the next step, local supply managers review the recommendations generated in step 3. After the recommendations and supporting data have been disseminated to the stakeholders, an ASL review board is convened. In it, the stakeholders present their views on which items should be stocked in the ASL. The stakeholders include local supply managers, maintenance technicians, motor pool officers, and representatives of the operational commander.
- **Step 5: Implement new ROs.** Once the ASL review board has reached agreement on the changes to be made, the fifth and final step is to enter the new ROs and ROPs into the system. (It is important to note that the final decision on all changes is subject

to commander approval. Automation, thus, does not dictate the ASL composition.)

In examining the stockage determination process, members of the SD PIT carefully reviewed the algorithms used by the Army to compute the breadth and depth of inventory. The PIT determined that these algorithms could be substantially improved to better account for several factors affecting inventory performance. These factors include the following:

- **Item cost.** Items vary greatly in cost, thus requiring tradeoffs in stocking very expensive items given a budget constraint.
- **Mobility.** Some items are too long or bulky to be stored in the limited number of containers, trailers, or flatbeds that are used to deploy most stocks.
- **Demand pattern.** Some items are needed at regular time intervals, while demand for others is inconsistent and variable.
- **Transition costs.** The Army often lacks sufficient funds to accept all recommended changes to existing inventories. For this reason, inventory improvement is a continuous process.

The DCB algorithm was designed to better account for these factors.

More Flexible Criteria for Determining Inventory Breadth

How does the dollar cost banding algorithm work? First, DCB expands the breadth of deployable inventories. The algorithm in the Standard Army Retail Supply System (SARSS) used a "one-size-fits-all" approach for determining whether or not an item qualified for stockage. An item not currently stocked would need nine requests over the prior review period (typically a year) to be added, while an item already stocked would need three demands to be retained.[1]

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[1] There were some exceptions to this policy. For example, parts used on aviation, missile, and other low-density equipment required fewer requests. In addition, on-site supply managers were allowed a specific percentage of items for which they could override the recommendations of the algorithm.

The 9/3 policy did not differentiate among items according to cost or criticality. Instead, these criteria were applied equally to a ten-cent screw and a $500,000 tank engine, despite the very different levels of investment and impact on readiness associated with each item.

The algorithm did not incorporate automated checks to the 9/3 policy to keep items off the ASL, including non-mission-essential items, items that could not be replenished through the standard supply chain, and items used to support weapon systems that were being phased out. Without such checks and given limited manpower to review the algorithm's recommendations,[2] deployable ASLs tended to be overstocked with nonessential, bulky items at the same time that many small, inexpensive, but critical items with fewer than nine demands were left off the ASL.

The DCB algorithm provides greater flexibility by adjusting the criteria for determining whether an item should be added or retained according to the item's criticality, size, end item density, and dollar value. It captures a more complete picture of demand by using a two-year demand history. As unit price goes down, so do the add/retain criteria. Under DCB, a small, inexpensive, but mission-critical item might be added to inventory with only two demands and retained with just one. DCB also incorporates automated checks for identifying nonessential, bulky items to be eliminated from deployable inventories.

Table 3.1[3] shows the DCB qualification logic. As depicted in the table, an item coded as mission-essential or that had at least one high-priority demand[4] and that had a price of less than $10 would

[2] The product of the SARSS system was a long printout that required lengthy manual review to try to apply such checks.

[3] Values in the table are given in demands per year, to be consistent with historical Army usage. The actual parameter tables (see Appendix C) used in the code are for the two-year review period.

[4] The priority assigned by the customer is not a fail-safe indicator of whether or not an item is mission-essential. However, the priority level can be combined with catalogue information for a better predictor than that provided by catalogue data alone. One pitfall of using item requisition priority is that many items may be stocked in the shops themselves (i.e., in the

require only two demands per year in the review period to be added. At the other end of the spectrum, a non-mission-essential item with all low-priority demands and a cost of more than $1,000 would require 1,000 requests per year in the review period to be added to the ASL (effectively keeping those items off the ASL). Many other variations exist between these two extremes.

DCB generally leads to the inclusion of more small, low-cost items with at least one high-priority demand in an SSA's ASL.[5]

Table 3.1
DCB Logic for Qualifying Items for the ASL

Essentiality Code	High-Priority Demand	< $10	< $100	< $1,000	> $1,000
Yes	Yes	2/1	3/1	6/3	9/3
Yes	No	4/2	4/2	6/3	9/3
No	Yes	2/1	3/1	6/3	9/3
No	No	12/3	15/3	30/3	1,000/3

PLL or the shop stock). If all customer requests were filled from shop inventory, only routine priority replenishment requests would go to the SSA. While these lower-priority requests may not necessarily reflect the essentiality of an item, they do reflect the multiechelon nature of the Army's supply chain.

This rule was deliberately set very conservatively. The intent was to make sure that small inexpensive items that could potentially deadline a weapon system are on the ASL. Having small inexpensive items on the ASL that did not drive readiness was considered less of a "sin."

[5] Many would argue that garrison demand patterns and maintenance philosophies would be likely to change during deployed operations, suggesting that ASLs containing many inexpensive items would be of less utility. However, empirical data from rotational units at the National Training Center (NTC) suggest that demand patterns, while increasing overall with increased tempo, do not shift dramatically in terms of composition. This result is not surprising, since the organizational shops, which generate the majority of demands in garrison, do not significantly shift maintenance concepts in deployed operations. Garrison data also suggest that most divisional Direct Support (DS) shops, particularly in maneuver brigades, spend a high percentage of their time working on inoperable end items rather than component repair. For each expensive part required to bring up a weapon system, several bolts, gaskets, and other inexpensive items are also likely to be needed. Further, a high proportion of home station failures occur during field exercises.

Computation of Stock Depth

DCB also more effectively determines how many of a given item should be stocked. To do so, the new approach abandons the Army's traditional "days-of-supply" (DOS) algorithm for determining the RO and ROP of each item that qualifies for the ASL.[6]

Figure 3.2 shows how the DOS depth logic worked. A day of supply is the average daily demand quantity computed over the review period. In the DOS logic, the depth of inventory, or RO, is the sum of the operating level (or order quantity), the order and ship time necessary to replenish stocks (known as the replenishment lead time, or RLT), and a safety level of five DOS. The ROP is the sum of the order and ship time and the five-day safety level. Together, the order and ship time plus the safety level determine the "lead time demand quantity," i.e., the stock on hand to continue filling customer requests from the time the ROP is reached until the replenishment is expected to arrive. Each of these DOS quantities is multiplied by a average daily demand rate, which is the total quantity demanded over the review period divided by the number of days in the review period.

The main shortcoming of the DOS method for calculating depth of inventory was the underlying assumption that demands are uniformly distributed throughout the year. For example, if requisitions totaling a quantity of 365 were received during a one-year review period, the underlying assumption of the DOS algorithm is that the demands came in at the rate of one per day (on 365 different re-

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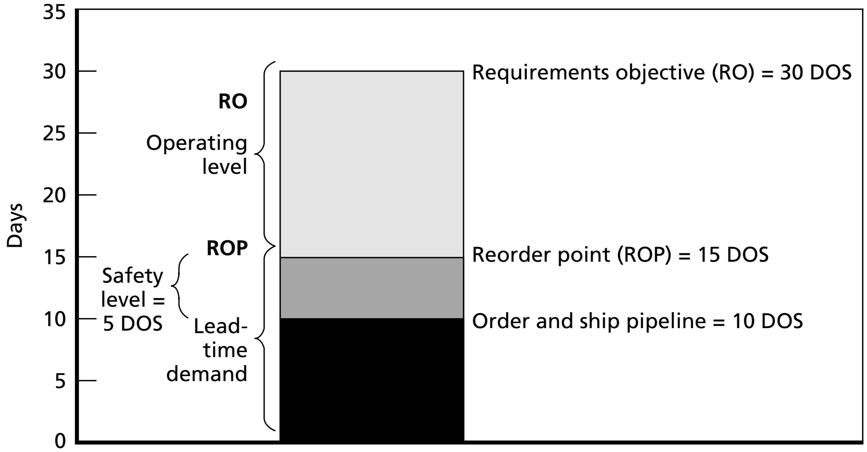
[6] The demand analysis algorithm implemented in SARSS is not exactly a DOS approach. Rather, demand quantity was discounted each month (from 1 to 0.95 to 0.90, etc.), resulting in a slightly lower average daily demand rate than would otherwise have been calculated under a strict DOS approach. Unfortunately, the demands associated with field training exercises, deployments, and other high-OPTEMPO events are not necessarily less likely to recur just because they happened some time ago. By discounting demands based on the time from the ASL review (a technique known as "exponential smoothing"), these demands would count less. Hence, local supply managers learned to initiate an ASL review immediately after high-OPTEMPO training events, when the demands would receive the greatest weight.

Figure 3.2
The Army's Traditional Depth Logic Is Based on Days of Supply (DOS)



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quests). That is, the DOS is equal to one. This would be true whether there was one requisition for quantity 365 or 365 requisitions for quantity one that arrived at the SSA in a highly variable fashion. Unfortunately, the DOS assumption of a uniform distribution is almost never the case, due to the highly variable OPTEMPO of deployable Army units, the variable nature of equipment failure, and the distribution of quantity requested per requisition.

Thus, the DOS approach frequently resulted in stock shortages, particularly in cases of variable or highly clustered demands. This method was unable to address two key challenges associated with stocking deployable SSAs:

- Inexpensive but critical items received the same safety level as expensive items despite the difference in investment.
- The highly variable OPTEMPO of deployable Army units can lead to highly variable demand (e.g., during training exercises). For example, some fire control parts are ordered in large quantities during tank gunneries but rarely during the rest of the year.

With the safety level set at five DOS, few items in SSA inventories had sufficient demands to warrant *any* safety stock at all, rendering the concept essentially meaningless.

A second shortcoming of the DOS approach is in the computation of the order quantity, which is equal to the difference between the RO and the ROP.[7] Because the algorithm failed to compute the order quantity as a function of unit cost, our ten-cent screw and $500,000 tank engine with the same mean demand rate would have the same order quantity despite the differences in inventory investment and required storage space associated with the items. This method could result in a loss of purchasing power, such as when capital was tied up in a large order quantity for an expensive item, or in unacceptable receiving section workload due to frequent ordering of low-cost items.

DCB addresses the second shortcoming by setting the order quantity using a modified economic order quantity (EOQ) formula. The classic EOQ formula[8] trades off the costs of holding items (e.g., costs of purchasing items, needed storage space) against the costs of ordering items (e.g., workload and monetary costs of ordering and receipting items). All else being equal, the order quantity for less expensive items will be greater than that for more expensive items. The modifications to the classical EOQ formula address practical issues about storage constraints for high-demand items and the minimum warehouse location size that must be allocated for low-demand items (see Appendix D).

Once the order size has been computed, the problem becomes one of computing the reorder point.[9] To address the main short-

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[7] There is an option in the Army's software to use a computation based on the economic order quantity (EOQ) to compute order quantity.

[8] See George Hadley and Thomas Whitin, *Analysis of Inventory Systems*, Englewood Cliffs, NJ: Prentice Hall, 1963, or William J. Stevenson, *Operations Management (Seventh Edition)*, New York: McGraw Hill Irwin, 2002, p. 551.

[9] This is the classic lot size reorder point problem; see Hadley and Whitin, op. cit., Chapters 2–4.

coming of the depth computation in the Army's algorithm (i.e., the DOS approach), the DCB algorithm computes the ROP using an iterative simulation approach. Actual demands from the two-year review period are used to create a demand profile for each item, i.e., a record of how many requisitions for an item were received and when the requisitions came in during the two-year period.

The simulation is then initiated at an inventory position (IP)[10] between the RO and ROP (within the range of the "operating level" shown in Figure 3.2 above). Each time the inventory position falls equal to or below the ROP, a replenishment order is initiated. The order quantity is equal to the difference between the RO and the current inventory position. Stocks are replenished after a delay referred to as the replenishment lead time (RLT); the RLT is computed from empirical data (see Appendix B); each time the reorder point is reached.[11] After all the demands have been processed, the average CWT associated with ROP is computed.

The average CWT is compared to the CWT goals, which vary according to item cost (see Table 3.2). Typically, the first time the simulation is run, the average CWT will exceed the goal. The simulation is therefore run iteratively, and the value of the CWT from prior simulations is used to adjust the value of the ROP until the average CWT goal is achieved. This process is repeated for every item that has had demand at the SSA.

The tighter the CWT goal, the higher the safety level required to avoid SSA backorders (which would increase the CWT computed

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[10] The IP is equal to on-hand assets plus assets due in from other supply sources minus assets due out to the customer.

[11] Customer requests that are filled by the SSA are assigned a CWT of one day in the simulation. The critical point in the simulation occurs each time the IP falls equal to or below the ROP. If the demands that occur before the replenishment arrives exceed the on-hand quantity, then an SSA backorder will occur and the CWT for that request will be greater than one day (but not greater than RLT days). During an actual SSA backorder, one of the sources of fill illustrated to the right of SSA fill in Figure 2.1 will eventually fill the request. The use of a constant RLT computed from these different sources of fill, which can vary dramatically in terms of responsiveness (see Figure 2.2), is an approximation.

Table 3.2
Variable CWT Goals According to Item Cost

Item Value	CWT Goal (in days)
< $10	1.3
$10 to $100	1.5
$100 to $1,000	1.7
> $1,000	2.0

in the simulation). All else being equal (which is never the case, since the order quantity is also a function of the price of the item), less expensive items will get more safety level than more expensive items. This is referred to as a variable safety level approach.

The order quantity, the safety level, and the length of time needed to obtain an item in the event of an SSA backorder all affect the CWT achieved in the simulation. For example, a large order quantity means that the inventory position will fall to the ROP less frequently, resulting in less time spent with a risk of stock-out. Hence, a smaller safety level will suffice to achieve a CWT goal for an item with a large order quantity in comparison with an item with similar demands but a smaller order quantity. However, an item that takes a long time to obtain if not available in the ASL (i.e., that has a long RLT) will require a larger safety level (which reduces the risk of stock-outs) to achieve the same CWT goal as an item that requires a short wait if not available in the ASL. In this way, DCB reduces the risk of stock shortages and more effectively sets depth levels that are appropriate for customer demand and replenishment patterns.

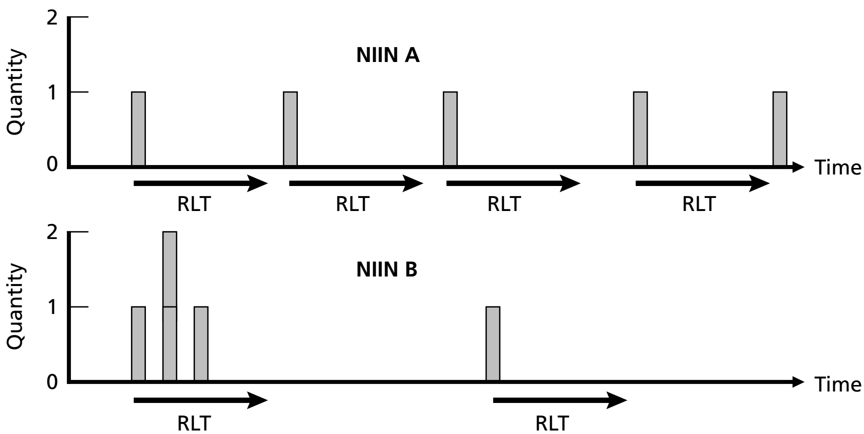
One important feature of the DCB algorithm is that it uses actual demands instead of attempting to fit a distribution to the total number of demands or the demand interarrival times.[12] Because the "cost banding" allows parts with very few demands (as few as one a

[12] Because a probability density function (PDF) is assumed and the demand data are then used to solve for the parameters to the PDF (e.g., the mean and variance), approaches that try to fit the lead time demands are often referred to as parametric approaches. Because DCB uses iterative simulation and does not rely on an assumed PDF, it can be called a nonparametric or distribution-free approach.

year for retention and two a year to be added), there would be very few demands to fit a distribution or estimate the parameters of a distribution. A more direct approach was thus desirable.

Figure 3.3 provides an illustration of how DCB better accounts for variations in demand than does the Army's traditional algorithm for calculating inventory depth. The top part of the figure shows the demand profiles for two different items (referred to by National Item Identification Number, or NIIN), each with the same number of total demands (five in this example). The profile for "NIIN A" is very predictable: one demand for the item is received at regular intervals. In contrast, the profile for "NIIN B" shows a variable demand pattern, with a cluster of demands early on followed by a single demand some time later.

Figure 3.3
The Dollar Cost Banding Algorithm Accounts for Variations in Demand



	DOS computation		Iterative simulation with CWT goal	
	RO	ROP	RO	ROP
NIIN A	1	0	1	0
NIIN B	1	0	4	3

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The table below the two demand profiles shows the different results achieved by the Army's traditional algorithm and DCB. The Army's traditional algorithm would compute the same DOS and hence the same RO and ROP for both items (same total number of demands divided by the same number of total days in the review period). This is indicated on the left side of the table, which shows an RO of 1 and ROP of 0 for both items. The use of the traditional algorithm would therefore result in the risk of a stock-out, particularly in the case of the clustered demands shown for NIIN B. In contrast, the DCB algorithm makes adjustments to account for the kind of variable demand patterns that can occur due to variations in OPTEMPO or equipment failure rates. Through iterative simulation with a CWT goal, the DCB algorithm results in a different RO and ROP for each item, as shown on the right side of the table. For NIIN A, the RO and ROP remain at 1 and 0, respectively, while for NIIN B, the RO is set at 4 and the ROP at 3, thus providing a higher level of safety stock to cover the item's variable demand pattern. Variable demand patterns such as the one illustrated here typically occur during periods of high OPTEMPO. Because periods of high OPTEMPO such as field training exercises best approximate how equipment is used during deployments, it is assumed that the DCB RO and ROP will perform better than the DOS approach during deployments as well.

Other Process Improvements

The prototype methodology used by RAND Arroyo Center to conduct an ASL review has resulted in several other improvements beyond the computation of the RO and ROP. The traditional process for setting inventory was ineffective in several ways:

- **The ASL review process was subject to lengthy delays.** This nonautomated step slowed the ASL review process substantially because of the large volume of data that had to be reviewed by supply managers, SSA supply technicians, maintenance technicians, and representatives of the operational unit commanders. The overall review process could take several months.

- **Implementation of inventory changes required lengthy, workforce-intensive activity.** Supply managers and participants in the ASL review board had few decision-support tools to aid in this process. As a result, the implementation of new ROs and ROPs typically involved tens of thousands of keystrokes (with inevitable errors) to enter the desired inventory levels into the system. SARSS allowed only two implementation options: either accept each and every recommendation from the demand analysis algorithm (which can be done as an automated process) or manually edit each recommendation at the routing identifier code (RIC, by which each SSA is identified) and NIIN level. Because of financial and mobility constraints, the second manual option was the only feasible choice.
- **Stockage policy implementation varied greatly across SSAs.** In practice, many SSAs did not have time to complete the inventory review on an annual basis. As a result, some SSAs were using inventory levels that had not been updated in several years. Although the ASL review board for each SSA (or group of SSAs) made most of the inventory decisions, these decisions tended to be ad hoc, with variation across SSAs and even at the same SSA at different times, based on changes in the priorities and experience of the staff involved.

Arroyo has sought to address these problems. One of the key improvements has come through the automation of many of the time-consuming and workforce-intensive steps required by the traditional ASL review process. The DCB algorithm uses a series of parameter tables, described in more detail in Appendix C, to automate many of the decision rules typically used by local supply managers. These include rules for identifying and screening out nonessential, bulky, cosmetic, and phase-out items that should not be included in deployable inventories. The algorithm automatically identifies certain nomenclatures and federal supply classes (FSCs) that should not be stocked. The algorithm also automates the process for identifying low-density and other items that would normally not qualify for inventory under the 9/3 add/retain criterion, but for which policy ex-

ceptions to 9/3 have existed. Previously, such exceptions had to be identified and implemented manually.

The process developed by RAND Arroyo Center to implement DCB also provides greater flexibility and more information to commanders and their staffs when doing ASL reviews. In contrast to the previous ASL review process, which gave supply managers only one unconstrained output (see above), Arroyo's process gives supply managers five alternatives, which span a range of budgetary and mobility constraints. Managers can then evaluate the alternatives in light of the tradeoff each requires in terms of performance versus cost. Table 3.3 provides an example of the five alternatives provided to a division's supply managers and commanders.

Table 3.3
DCB Provides Five Alternatives to Accommodate Different Levels of Budget and Mobility Constraints

Alternative	Net Buy	Less OMA[a]	Net Turn In	Constraints
1	$4,217,585	$3,985,011	$655,860	All lines with net reduction or increase in RO > $50,000 frozen at existing RO[b]
2	$1,272,221	$1,207,695	$655,860	Net increase in RO limited to $5,000
3	$1,070.772	$1,012,813	$660,241	Add not allowed if extended cube > 1.5 cu ft, unless > 25% of demands are Issue Priority Group 1 (IPG 1) and > 60% of demands are IPG 1 or 2 Add criteria increase to 5 demands unless > 25% of demands are IPG 1 and > 60% IPG 1 or 2 (ground USA only)
4	$688,584	$657,232	$658,713	Net increase in RO limited to $2,000
5	$336,488	$321,151	$658,713	Net increase in RO limited to $800

[a] "Less OMA" is the investment costs after assets available on post above the RO are utilized to offset the costs of adds and increases.
[b] Computation is done by NIIN looking across all the SSAs in the run (e.g., all the SSAs in a division).

The table offers a glimpse of the flexibility inherent in the overall ASL review process used with the DCB algorithm, as well as the tradeoffs involved in implementing changes to inventory. The alternatives range from the most expensive Alternative 1—which requires a net buy of more than $4.2 million—to the least expensive Alternative 5—which requires a net buy of only $336,488. Varying levels of investment are each associated with different constraints on line cost and cube, as indicated in the column on the right.

To help supply managers assess the tradeoffs involved in the alternatives, each alternative is simulated against actual demand histories to estimate future performance. This simulation operates in a fashion similar to the iterative simulation used to set the inventory levels that achieve the CWT goals (i.e., the actual demand history is played day by day while inventory position, replenishments, and any ASL backorders are tracked). The investment and mobility requirements associated with each alternative can then be used with the predicted performance (e.g., CWT and ASL fill rate) and workload (number of issues and receipts required to fill the customer requests) to establish tradeoffs, which are communicated to the leadership and local supply managers in a decision brief. The combination of performance and resource metrics allows managers to make informed decisions. This process also lends itself to continuous improvement as local supply managers can iteratively seek higher levels of performance over multiple ASL reviews and track predicted versus actual performance after the ASL review results have been implemented.

Advantages of DCB over the Army's Traditional Inventory Management Method

As this chapter has shown, the DCB algorithm offers several advantages over the Army's traditional method for calculating inventory. Table 3.4 summarizes the differences between the two approaches.

Table 3.4
Comparison of Army's Traditional Inventory Management Method and DCB

Traditional Method	Dollar Cost Banding
Uses "one-size-fits-all" 9/3 approach for determining whether or not to stock a particular line (exceptions for low-density systems to 3/1, but no easy way to identify and implement the exceptions).	Adjusts criteria for determining whether an item should be added or retained according to the item's criticality, mobility requirements, end item density, and dollar value.
Lacks automated checks to keep nonessential items off the ASL.	Automates the process for identifying nonessential, invalid, and bulky items to be removed from deployable inventories.
Uses "days-of-supply" approach for calculating depth of stockage; assumes that demands are distributed uniformly.	Sets CWT-driven goals based on unit price (variable safety level). Accounts for wait time if the item is not available locally and variations in demand rates resulting from changes in OPTEMPO and equipment failure rates.
Does not compute order quantity as a function of unit cost.	Uses modified economic order quantity formula to increase the order quantity for less expensive items.
Provides only two options for new ROs and ROPs: either accept all recommendations as part of an automated process or manually edit each recommendation.	Automates the implementation process and provides a range of five alternatives that can be used to accommodate the budgetary and mobility constraints of the organization.

CHAPTER FOUR

Implementation

Units that have used dollar cost banding for an ASL review have seen improved performance. In this chapter we will look at some examples of the kinds of improvements made possible. We have selected examples that illustrate the effectiveness of DCB across unit types with different equipment to support and different storage constraints for mobility. We look first at the use of DCB in the 101st Airborne Division (Air Assault) at Fort Campbell, Kentucky. We then discuss the use of DCB by the 3rd Infantry Division, a heavy division located at Fort Stewart and Fort Benning, Georgia, and the Army's Armor Center and School at Fort Knox, Kentucky.

101st Airborne Division (Air Assault)

In 1997, the 101st Airborne (101st Air Assault) Division at Fort Campbell, Kentucky, became the first site to apply the Velocity Management methodology to improve log processes and the first to conduct an ASL review using a prototype of the DCB algorithm. Fort Campbell was selected as a pilot site because of its longtime participation in the VM initiative, which dates back to 1994. The supply units within the 101st consisted of seven Class IX SSAs, including three ground forward support battalions (FSBs), one main support battalion (MSB), and three aviation intermediate maintenance companies (AVIMs). The SSA in an FSB of the 101st has to support a wide variety of equipment of different densities. There are five to

seven ISU-90 containers and a limited amount of bulk storage available for the parts to support this equipment.

Initial ASL Improvement Efforts

Before the prototype of DCB was implemented at Fort Campbell, Arroyo analysts used the existing SARSS-2AC Availability Balance File (ABF) and CTASC document history to determine ways to free up the space and the resources needed for increasing the number of ASL lines. An initial review of baseline data for March 1997 showed significant shortfalls between the inventory in the SSAs and customer demands. SSA fill rates of less than 20 percent were common in the forward and aviation SSAs, although the MSB had higher SSA fill rates. SSA fill rates for high-priority requests were typically only slightly higher. Accommodation rates were very low, and satisfaction rates were problematic as well. The process of improving inventory performance at Fort Campbell was made more challenging because existing inventory levels did not accurately reflect the demand history.[1]

During the initial improvement phase, the research team identified items without demands in the last year for turn-in (i.e., deletion from the ASL),[2] items that could be cross-leveled across SSAs, and low-cost items for addition to the ASL. Implementing these changes significantly reduced the dollar value of the RO for each of the SSAs. Divisionwide, the value of the RO was reduced from over $20 million to about $10 million. Most of the dollar value associated with this RO reduction resulted from deleting a few high-dollar lines that had not had a demand in over a year. It should be noted that the total reduction in RO value occurred largely because the division did not have the funds to purchase the recommended adds and increases (totaling almost $16 million). Had the funds been available to resource

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[1] This mismatch was related to the conversion to SARSS and restructuring of the aviation SSAs.

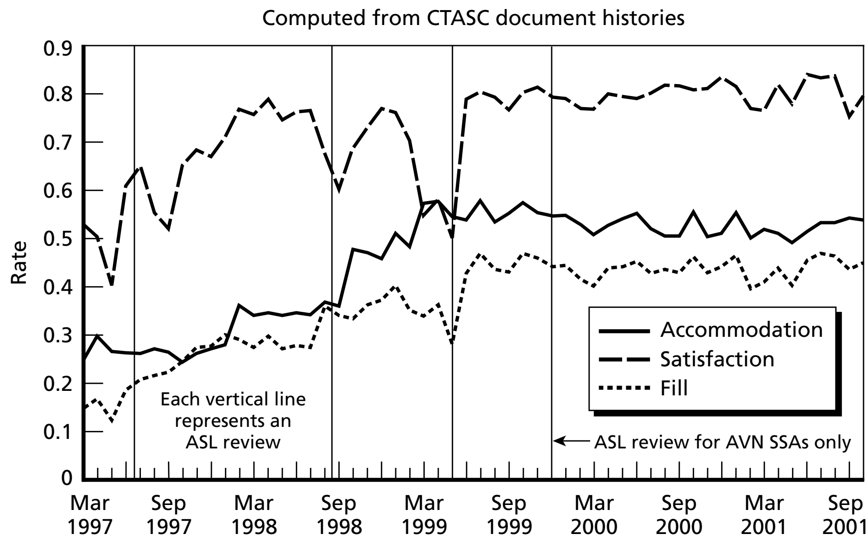
[2] Items that had demands were not deleted from the ASL in anticipation of reducing the add/retain criteria for low-cost items.

all the adds and increases called for, the value of the division RO would have increased. Although the division was not able to fund all the recommended adds and increases, inventory performance still improved substantially. (See the leftmost vertical line in Figure 4.1.) These changes were input manually in June and July 1997. The SSA fill rate rose from 10–20 percent to 20–30 percent (see Figure 4.1). As the supporting SSA filled more customer requests, overall CWT was also reduced.

ASL Reviews Using DCB

During the period following the initial implementation, changes were made in the organization of the main warehouse to free up space and improve flows. For example, in the MSB, warehouse personnel initiated a consolidation effort that reduced the number of ISU-90 containers from 40 to 19—without reducing the depth or breadth of

Figure 4.1
Fill, Satisfaction, and Accommodation Rates for the 101st AA Increase Steadily as DCB Was Used for ASL Reviews



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stock. This consolidation allowed the storage site to move all 19 remaining ISU-90 containers into the warehouse. At the same time, the Site Improvement Team (SIT) improved the flow through the warehouse and receiving area. Similar improvements were carried out at the other SSAs.

The next phase of the improvement effort marked the first time that a version of the DCB methodology was used to generate recommended ASL changes. Initially, only "cost bands" were added to the qualification logic of the algorithm.[3] The 9/3 criterion was relaxed to allow small, but essential, low-cost items to be added to inventory. The methodology was also adjusted to take into account the variability in an item's demand pattern and item cost when determining recommended depth and also to remove large, bulky items (that were not readiness drivers) from inventory. The changes recommended were posted in stages in July of 1998 (marked by the second vertical line in Figure 4.1). SSA fill rates across the division increased steadily to between 30 and 40 percent, even though the initial improvement phase had already added the fastest-moving lines.

These changes further reduced the dollar value of the divisionwide sum of ROs from $10.2 million to $9 million. This net reduction resulted from some $750,000 in adds and increases with almost $2 million in deletes and decreases. Again, the primary reason the value of the ROs went down was that although most of the decreases and deletes were accepted, there were only limited funds available for the adds and increases recommended.

The next ASL review for the 101st used an improved version of the DCB algorithm. The resulting changes were input to the system in May 1999. This iteration led to changes in the dollar value of the RO at each SSA. As had been the case in the prior ASL reviews, there were still significant budget and mobility constraints that limited the improvements possible, although the value of the divisionwide ASL

[3] The qualification was later expanded to reflect additional parameters, including (1) density of the supported end item, (2) the number of high-priority demands, (3) the number of recent demands, and (4) item weight and cube.

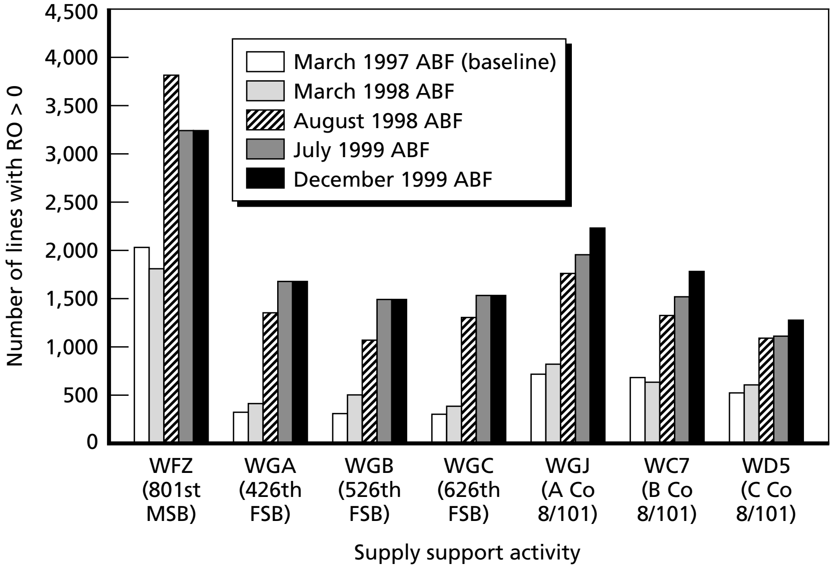
increased from $9 million back up to $10 million. All of the SSAs except the MSB increased in RO value. Because the ASLs were now demand-supported, there were very few deletes (other than in the MSB). As the FSBs and AVIMs gained experience operating ASLs with more lines, they were willing to accept further increases in the number of lines. However, the subsequent increases in lines were smaller in magnitude than the increases experienced in the initial shift to DCB. Accommodation rates increased as the new ROs were set. Satisfaction rates dropped initially until the materiel associated with the added lines began to arrive, but then recovered, and SSA fill rates increased, approaching 50 percent at the 626th FSB. Divisionwide fill rates increased to between 40 and 50 percent.

Then in December 1999 an ASL review was run using DCB for just the three AVN SSAs. This was done to focus the performance improvements on the AVN SSAs, which tended to have higher-cost items than the main support battalion and forward support battalions. While the overall SSA fill rate across the division did not increase appreciably, the three AVN SSAs achieved increases in SSA fill rate. Again, budget constraints limited what could be achieved, with the best results for A Co 8/101, which supported primarily transport and utility aircraft (which use less expensive parts than the combat aircraft).

Figure 4.2 depicts the significant increase in the breadth in each of the ASLs after the first ASL review using DCB (the increase is reflected in the August 1998 ABF). The number of lines in the FSBs doubled or tripled, while the number of lines in the MSB more than doubled. Reflecting the budget constraints, much of the increase occurred in lines that cost less than $10, while a significant number of lines were also added for items costing between $10 and $100. The number of lines in the aviation SSAs increased modestly during the ASL review that was posted in December 1999.

Figure 4.3 depicts the changes in RO dollar value by SSA. It should be noted that the largest decreases occurred in the initial improvement phase before any ASL reviews using the DCB algorithm had been conducted. Since the deletes were limited to items with no

Figure 4.2
Increases in Breadth at Fort Campbell with DCB



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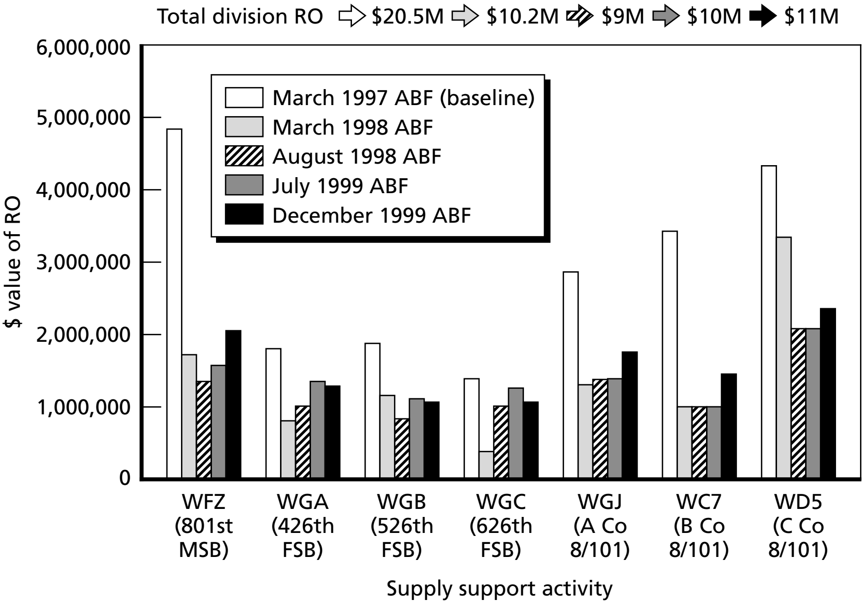
demands over a one-year review period, it is likely that many of these reductions would have occurred under DCB (although DCB uses a two-year review period). The increases to the RO in each ASL review were severely limited by budget constraints.

The results achieved by the 101st Airborne provided an example of the improvements possible with DCB. As will be seen in the next subsection, the DCB methodology was subsequently improved to provide supply managers with the five alternatives described in the previous chapter.

3rd Infantry Division

When the Velocity Group made the decision to pilot the DCB algorithm prototype at a heavy division in 1998, Forces Command (FORSCOM) recommended the 3rd Infantry Division (3rd ID),

Figure 4.3
RO Value Between ASL Reviews at Fort Campbell



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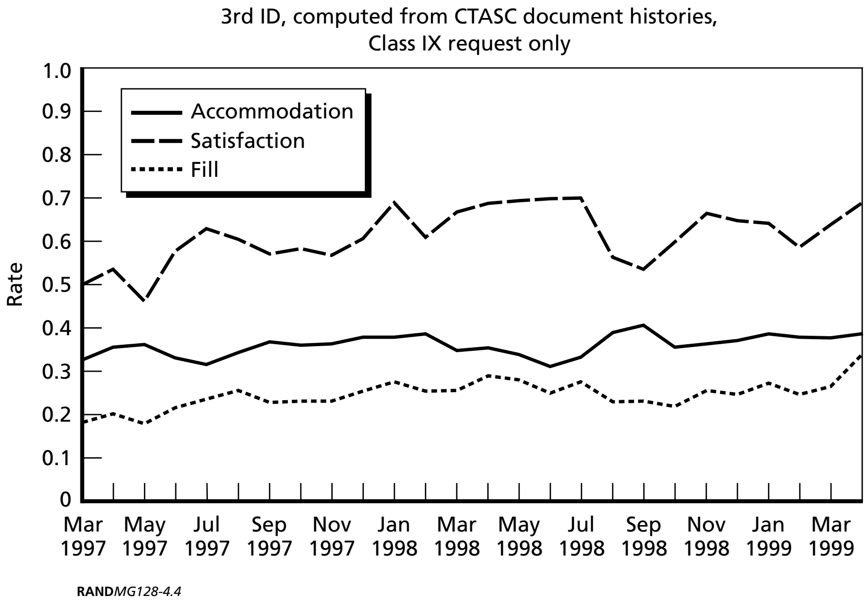
which is a mechanized infantry division with a large fleet of Bradley Fighting Vehicles and M1A1 Abrams tanks.

Need for Improvement

Initial analyses of inventory performance at the 3rd ID showed the need for improvement. To conduct a baseline assessment, Arroyo analysts tracked and analyzed data provided by the SARSS-2AC ABF and the CTASC document history.

The fill, satisfaction, and accommodation rates derived from these sources are shown in Figure 4.4 for the two years prior to the use of DCB. Performance in all three areas was poor. Clearly there was a significant gap between the inventory on the ASL and the SSA's customer demands. SSA fill rates ranged from 20 to 30 percent. Accommodation rates of 30 to 40 percent suggested that ASLs were not carrying enough lines. Satisfaction rates of 50 to 70 percent were well

Figure 4.4
Fill, Accommodation, and Satisfaction Rates at the 3rd ID Prior to the Implementation of Dollar Cost Banding



below the Department of the Army goal of 85 percent, suggesting insufficient depth.

Low SSA fill rates resulted in lengthy CWT. The 3rd ID's CWT was long and variable, with a median CWT of 10 days and mean CWT as high as 36 days in some months. The median CWT for high-priority (IPG 1) requests was only slightly better than that for low-priority requests.

The poorest performance was found in the FSBs and the ASB. As shown in Figure 4.5, while the MSB typically attained fill rates of 30 to 40 percent,[4] FSB SSA fill rates hovered around 20 percent, and the ASB SSA fill rate was barely above 10 percent.

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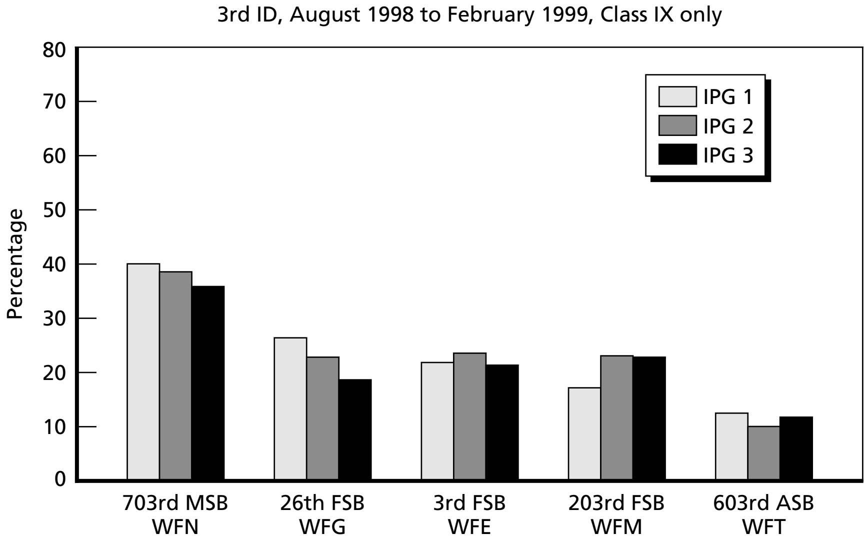
[4] As noted in Chapter Two, all satisfaction and fill rates in this report count partial fills as satisfied. By doing this we were able to maintain consistent definitions with the earliest data

Figure 4.5
Fill Rates by SSA for the 3rd ID Prior to the Use of DCB



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A walkthrough of the SSAs at the 3rd ID also revealed problems with warehouse operations. To store inventory, the 3rd ID relied on vans and trailers. The available storage space was very poorly utilized, with empty locations and drawers in every cabinet and underutilized cabinets in every trailer. In addition, improvements were needed in warehouse work flows to allow materiel to move through the warehouse more quickly and to reduce workload. It was clear that with better use of storage facilities, the SSAs would be able to increase the number of lines dramatically while still decreasing total footprint.

First ASL Review with DCB

DCB was used for two ASL reviews in the period documented in this report. The initial ASL review took place in May 1999. At first, the

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used in this report and track trends accurately. Typically, satisfaction rates may be one-half to three points lower if partial fills are not counted as satisfied.

Division Support Command (DISCOM) commander and his staff were reluctant to use DCB in an ASL review. Although inventory performance at the 3rd ID was unsatisfactory, there were concerns that a new algorithm might result in higher cost and reduce mobility. To mitigate these concerns, Arroyo analysts agreed to support the initial ASL review using DCB within a fixed budget and with strict limitations on the number of lines that could be added to the FSB ASLs. Recommended changes to the ASL were then provided to local supply managers in a spreadsheet that managers could use to identify critical and high-value items and decide which changes to implement.

In preparation for the review, Arroyo worked with local supply managers to develop ideas about how to redesign their storage. The division was converting to a new series of storage vans and had ordered new cabinets. This consolidation allowed the warehouse to be reconfigured, increasing mobility and decreasing the time required to store and pick items.

Adjustments were then made to the inventory levels according to the decisions made by supply managers who had reviewed Arroyo's recommendations. The use of DCB in the ASL review expanded both the breadth and depth of inventory while reducing total inventory investment and the cubic feet of parts stocked. The changes made during the first phase of DCB are summarized in Table 4.1.

Table 4.1
Summary of Changes to ASLs at the 3rd ID During the Initial Implementation of DCB

Unit	RIC	Number of Lines (before)	Number of Lines (after)	Dollar Value of RO (before)	Dollar Value of RO (after)	Extended Cubic Feet (before)	Extended Cubic Feet (after)
703rd MSB	WFN	4,050	4,394	$28,240,057	$24,877,397	40,716	28,900
3rd FSB	WFE	1,254	1,810	$6,671,202	$6,741,335	8,500	7,600
26th FSB	WFG	1,002	2,084	$7,206,136	$7,307,012	8,621	7,714
203rd FSB	WFM	1,675	2,327	$5,769,545	$5,885,554	8,722	8,430
603rd ASB	WFT	981	1,339	$10,347,477	$8,641,225	2,871	3,500
3rd ID	Total	8,962	11,954	$58,234,418	$53,452,523	69,430	56,144

The dollar value of the RO was reduced from \$58.2 million to \$53.5 million, a decrease of more than \$4.7 million (\$1.6 million in buys and \$6.4 million in draw down). The number of lines in the division was substantially increased, from 8,962 to 11,954—an increase of more than 33 percent, with the largest increases occurring in the FSBs and the ASB. The extended cube of the RO for parts stocked was reduced from 69,430 to 56,144. The MSB was able to reduce the number of trailers used to store the ASL, and bulk storage requirements were also reduced.[5]

The changes in the ROs and ROPs led to immediate improvements in SSA fill, accommodation, and satisfaction rates, as can be seen on the left side of Figure 4.6.[6] The vertical line labeled "Phase 1" shows the point when changes to the ROs and ROPs from the first review with DCB were posted to SARSS. After the necessary transactions to update the RO and ROP values in the ABF were processed, SSA fill rates rose from 20–30 percent to nearly 40 percent. Satisfaction rates rose from around 60 percent to 70–80 percent. Accommodation rates rose from 30–35 percent to 45–50 percent.

As a result of improved SSA fill performance, CWT also began to improve, as shown in Figure 4.7. The reduction in CWT occurred due to the increased number of requests being filled from the direct supporting SSA. After the first ASL review, improvements were seen in mean CWT (dropped from over 20 days to about 15 days), median CWT (dropped from around 10 days to 6 days), and the 75th percentile of CWT (dropped from around 15 days to 10 days). The 95th percentile of CWT, which is also tracked as a VM metric, is largely a function of supply sources beyond the SSA and hence does not trend with SSA fill rates. The mean CWT also reacts to the outliers, which drive the 95th percentile, and as a result may not always track with improved SSA fill rates.

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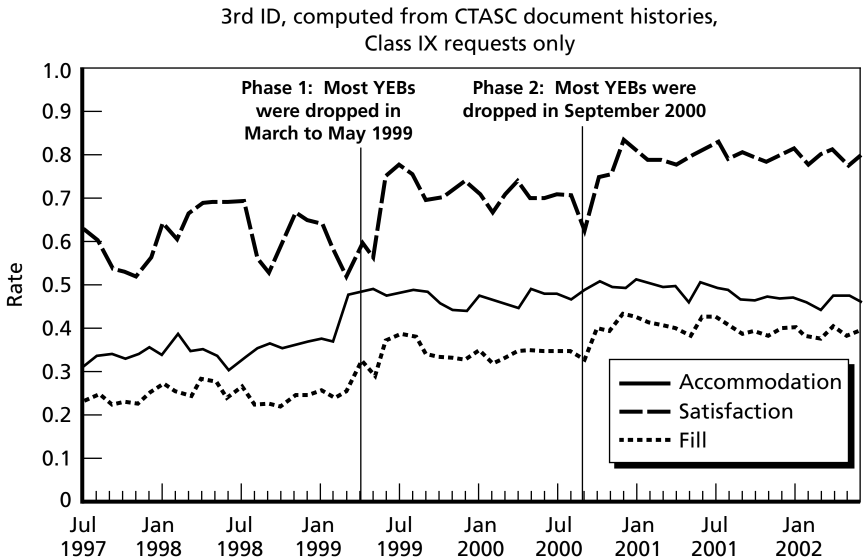
[5] Because the utilization of storage space had been dramatically improved, the FSB and ASB were able to absorb the increased lines without adding additional trailers or containers.

[6] The chart also includes data after the second ASL review using DCB was executed, which will be discussed later in the chapter.

Figure 4.6
Fill, Satisfaction, and Accommodation Rates for the 3rd ID Before and After DCB



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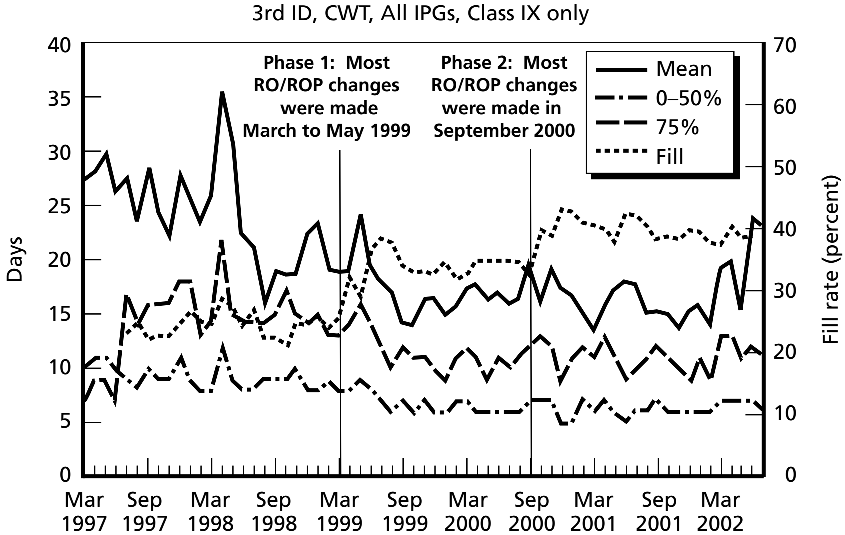
Second ASL Review with DCB

After the initial ASL review using DCB in May 1999, performance stayed fairly constant over the next year and a half.[7] Then, at the beginning of FY01, the 3rd ID conducted another ASL review.[8] The prior ASL review had been constrained to accommodate the concerns of the division with respect to the number of lines in the SSAs and to allow the units to gain experience with the redesigned warehouse

[7] It is recommended that installations adjust inventory levels every 6–12 months in case demand patterns have shifted.

[8] In fact, since the previous ASL review used DCB, it was necessary to continue using DCB to retain many of the lines that had been added. Because DCB lowers the add/retain criteria for low-dollar critical items, units risk deleting many of the lines that were added if in a subsequent ASL review they go back to 9/3 criteria regardless of unit price.

Figure 4.7
Reductions in CWT Since ASL Redesign



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storage and work flows. However, the fastest moving of the lines that qualified had been added. The improvement made possible by the prior ASL review with DCB suggested that returns would necessarily be smaller in the second ASL review with DCB. Since the time of the first iteration, however, Arroyo had improved the DCB algorithm and had developed a five-alternative format for reviewing and changing inventory levels. These alternatives allowed supply managers to see predicted performance for each of the five alternatives over the demands experienced in the previous two years (the review period). They could then evaluate each option in relation to performance, cost, and mobility.

The investment and constraints associated with each of the five alternatives (as discussed in Chapter Three) for the September 2000 ASL review are summarized in Table 4.2.

As can be seen, Alternative 1 required a substantially larger investment than Alternative 5. Restrictions were added with each alter-

Table 4.2
Summary of Five Alternatives for 3rd ID in September 2000

January 4, 2000 ABF	Net Investment	Net Investment: OMA	Net Turn-in	Constraints
Alternative 1	$8,874,870	$8,714,526	$2,191,395	All lines with net reduction or increase in RO > $50,000 frozen at existing RO
Alternative 2	$2,642,790	$2,603,842	$2,191,395	Net increase in RO limited to $5,000
Alternative 3	$2,243,239	$2,207,514	$2,214,988	Adds not allowed if extended cube > 2 cu ft unless > 25 percent of demands are IPG 1 and 60 percent of demands are IPG 1 or 2 (ground only)
Alternative 4	$2,064,704	$2,048,642	$2,205,962	Net increase in RO limited to $2,000
Alternative 5	$682,540	$670,765	$2,205,640	Net increase in RO limited to $800

native to meet different levels of budget and storage constraints. The constraints are additive from Alternative 1 to Alternative 5. The computation of net investment reflects the fact that the algorithm accounts for cross-leveling across SSAs. For example, if the DCB algorithm recommended an RO increase of three at one SSA for a NIIN and RO decrease of two at another SSA for the same NIIN, the net investment would be one times the unit price.[9] The term "net increase" refers to a single NIIN change in the sum of the ROs across all the SSAs in the division times the unit price.

Table 4.3 shows the simulation results for the five alternatives considered for the 3rd ID in September 2000. (See Table 3.3 for definition of the constraints imposed to generate the five alternatives.) The simulation of the five alternatives indicated that more lines could be added to the FSBs and the ASB, but that performance improvement would be limited, as the most advantageous lines (those with the most demands) had already been added. However, one clear benefit would be improved depth, which would also result in better fill rates.

[9] The net investment computation is an approximation of the costs associated with an ASL review. The actual costs of replenishment documents that must be funded when changes to the inventory levels are posted are a function of current inventory position and changes to the ROP as well.

Table 4.3
Simulation Results for the Five Alternatives Considered for the 3rd ID in September 2000

	703rd MSB (WFN)			3rd FSB (WFE)			26th FSB (WFG)			203rd FSB (WFM)			603rd ASB (WFT)		
	accomo	sat	fill	accomo	sat	fill	accomo	sat	fill	accomo	sat	fill	accomo	sat	fill
6/1/00 ABF	61.2%	74.3%	45.5%	46.0%	66.5%	30.6%	50.7%	68.5%	34.7%	51.0%	65.6%	33.5%	30.4%	58.2%	17.7%
Alt 5	64.3%	80.8%	51.9%	57.7%	78.2%	45.2%	59.6%	78.2%	46.6%	56.8%	77.0%	43.7%	43.2%	74.2%	32.1%
Alt 4	64.7%	82.4%	53.3%	59.4%	80.6%	47.8%	60.5%	80.3%	48.6%	57.5%	79.5%	45.7%	44.7%	76.1%	34.0%
Alt 3	65.3%	85.3%	55.7%	61.2%	84.9%	52.0%	62.0%	84.2%	52.2%	58.7%	83.9%	49.3%	46.3%	79.8%	37.0%
Alt 2	69.6%	85.4%	59.4%	68.4%	85.2%	58.3%	68.8%	84.4%	58.1%	65.0%	84.2%	54.7%	47.3%	80.0%	37.9%
Alt 1	70.1%	88.2%	61.8%	70.5%	89.8%	63.3%	70.7%	88.7%	62.8%	66.5%	88.5%	58.9%	48.8%	83.3%	40.6%

Although the simulation results suggested that all five alternatives would improve upon current performance, the level of expected improvement differs for each. For example, moving from Alternative 2 to Alternative 3, which introduces storage space constraints, has the biggest impact on predicted accommodation rates as it reduces the number of lines accepted.

All five alternatives provide relatively similar improvements in satisfaction rates. The reduction in predicted satisfaction rates from Alternative 1 to Alternative 5 occurs as the depth of more expensive lines is not brought up to the recommended levels due to budget constraints on lines with net increases. As additional restrictions are added, the simulation predicts that supply performance will drop off. Thus, fill rates are higher for Alternatives 1 to 2 than for Alternatives 4 and 5. Table 4.4 summarizes the lines, investment, and cube for each SSA associated with Alternatives 3–5, the only alternatives considered by the 3rd ID.

During the second ASL review with DCB, local supply managers reviewed the recommendations and the additional information provided by the five alternatives concerning inventory tradeoffs and accepted the recommendations with very few changes. Due to budget constraints, managers selected the least expensive option, Alternative 5.

After the second iteration of DCB, which occurred in September 2000 (see second vertical line in Figure 4.6 denoted "Phase 2"), supply performance at the 3rd ID improved further. SSA fill, satisfaction, and accommodation rates all rose, with particular improvement seen in satisfaction rates, which remained consistent at about 80 percent.[10] Combined with a rise in accommodation rates to 50 percent, SSA fill rates rose to about 40 percent.

[10] The 80 percent satisfaction is a composite value across all NIINs. For lines where the DCB recommended levels are accepted, performance is generally good, at or above 90 percent satisfaction. However, there are many lines for which the recommended increases in depth were not accepted due to budget constraints. These NIINs could have very low satisfaction rates, which drive the overall satisfaction level down to 80 percent.

Table 4.4
Lines, Value, and Cube for the Three Alternatives Considered by 3rd ID in September 2000

Unit	RIC	Current # of Lines	Current RO $ Value	Current Cubic Feet	Alt 3 # of Lines	Alt 3 RO $ Value	Alt 3 Cubic Feet
703rd MSB	WFN	4,394	$24,877,397	28,925	4,381	$23,548,413	26,743
3rd FSB	WFE	1,810	$6,741,335	7,657	3,195	$6,966,584	7,548
26th FSB	WFG	2,084	$7,307,012	7,748	3,322	$7,808,719	7,296
203rd FSB	WFM	2,327	$5,885,554	8,464	3,184	$6,424,088	7,958
603rd ASB	WFT	1,339	$8,641,255	3,503	2,246	$8,733,000	2,856
3rd ID	Total	4,469	$53,452,553	56,298	16,328	$53,480,805	52,401

Unit	RIC	Alt 4 # of Lines	Alt 4 RO $ Value	Alt 4 Cubic Feet	Alt 5 # of Lines	Alt 5 RO $ Value	Alt 5 Cubic Feet
703rd MSB	WFN	4,363	$23,421,341	26,771	4,352	$23,401,199	26,824
3rd FSB	WFE	3,089	$6,740,800	7,548	2,989	$6,642,448	7,548
26th FSB	WFG	3,241	$7,588,336	7,296	3,168	$7,507,888	7,296
203rd FSB	WFM	3,112	$6,144,445	7,958	3,063	$6,056,692	7,958
603rd ASB	WFT	2,171	$8,416,373	2,857	2,096	$8,321,227	2,857
3rd ID	Total	15,976	$52,311,295	52,430	15,668	$51,929,454	52,484

Figure 4.7 above shows the effect the ASL changes had on median, 75th percentile, and mean CWT. The reductions in CWT expected from increased SSA fill rate were offset by increases in the time from the document date to the SARSS establish date (the time from when customers create requests in their maintenance system until they transfer the data to the supporting SSA) in the period following the ASL review. Also, the increase in the SSA fill rate was not large enough to affect the percentiles tracked in the figure, though the mean did decrease.

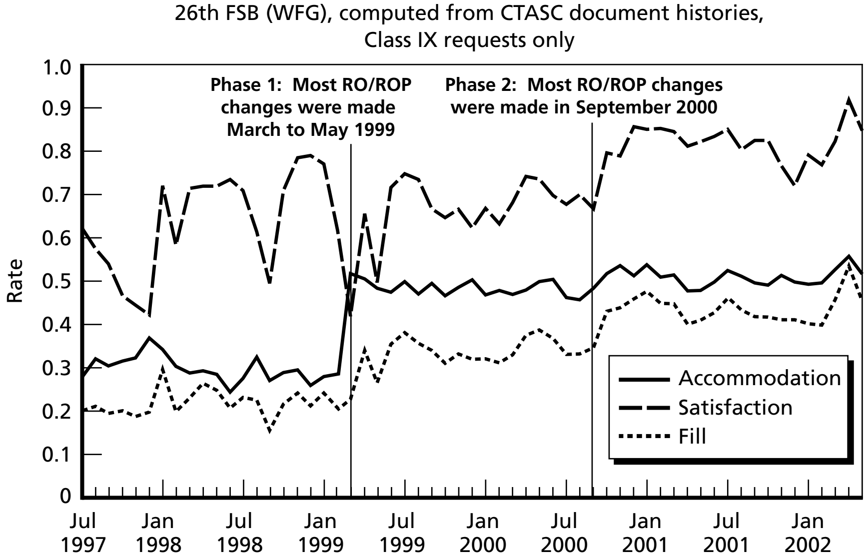
Performance also improved significantly in the FSBs, as depicted in Figure 4.8. The figure displays accommodation, satisfaction, and SSA fill rates for the 26th FSB of the 3rd ID. Most of the overall division increase in accommodation rates came from the FSBs, which added slower-moving lines that were inexpensive and small but had high-priority requests.

In summary, before doing an ASL review using DCB, the 3rd ID had an accommodation rate below 30 percent; after two ASL reviews with DCB the accommodation rate rose to over 50 percent, in line with the predicted performance. The FSBs improved the most, resulting in much more robust support capability were a single brigade to deploy. Similarly, satisfaction rates, which had been low and highly variable, rose to the 80–90 percent range and became more consistent. SSA fill rates also showed great improvement. Before the ASL reviews with DCB, SSA fill rates hovered at or below 20 percent but rose to over 40 percent.

As expected, given the bias toward high-priority demands in the qualification criteria, SSA fill rates have been highest across the division for IPG 1 requests.[11] The SSA fill rate for IPG 1 requests for the

[11] All SSAs increased their IPG 1 SSA fill rates substantially when comparing the six months before the first ASL review and the six months following the second ASL review. However, the 203rd FSB (RIC WFM) had a slightly higher SSA fill rate for lower-priority requests—a pattern that had existed before the first ASL review as well (see Figure 4.2). Also, the ASB had higher fill rates for the lower priorities. Both of these cases no doubt reflect the inventory investment constraints that were applied during both of the ASL reviews.

Figure 4.8
26th FSB Rates After DCB



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six months following the second ASL review with DCB was 42 percent across the division versus 23 percent in the six months prior to the first ASL review. The IPG 1 SSA fill rate was 2–4 points higher than the IPG 2 and 3 SSA fill rates. One of the FSBs had an IPG 1 SSA fill rate of 52 percent versus an IPG 3 SSA fill rate of 41 percent in the six months following the second ASL review.

Armor Center and Armor School at Fort Knox

Fort Knox, Kentucky, is home to the Army's Armor Center and School. Three factors made Fort Knox an ideal candidate for doing an ASL review using DCB: (1) high equipment OPTEMPO, (2) centralized inventory with room for expansion, and (3) fast and reliable requisition wait times for replenishments from national inventories.

Although the SSA at Fort Knox is not deployable, the site's role as home to the Army's armor training school means that the supply support needs are similar to those of deployed units. In fact, soldiers training at Fort Knox rotate into the same equipment. Thus, a high OPTEMPO is sustained, with fewer and shorter intervals of low OPTEMPO during which equipment can be brought back up to fully mission-capable status.

The Fort Knox VM SIT had been very active and consolidated almost all the inventory on post into a single SSA (the exception being some PLL, bench, and shop stocks that remained in the maintenance shops). The warehouse at Fort Knox had excellent high-density storage aids that would allow the SIT to significantly increase the number of lines in the warehouse.

The SIT had also worked to reduce order and ship times from DLA distribution centers. The vast majority of the shipments to Fort Knox arrive on a daily scheduled truck that brings shipments of all priorities from the distribution center in Susquehanna, Pennsylvania. The result is high confidence that lead times for low-priority stock replenishment requests will be short and reliable.

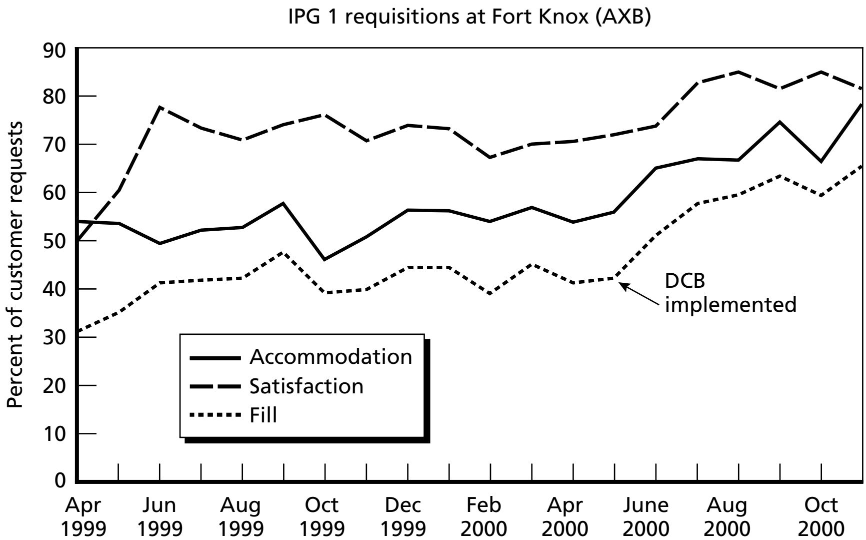
Before using DCB, the SSA at Fort Knox had ROs for only 2,861 lines with a value of $29 million. After verifying the warehouse capacity, Arroyo provided the Fort Knox VM SIT with the standard decision brief based on the five alternatives that depicted the resource-versus-performance tradeoffs. Because mobility was not a concern for the nondeployable SSA, investment was the primary constraint. The Fort Knox SIT worked to secure funding and ultimately chose Alternative 2. While this alternative still froze the levels of the most expensive items, it allowed Fort Knox to progress farther along the performance improvement curve than any of the deployable units using DCB had been able to go.

The recommendations resulted in an up-front investment of $700,000 to fund adds and increases. Deletes and decreases worth over $2 million were also implemented, resulting in a net decrease in

the dollar value of the RO of $1.3 million (from $29.2 million to $27.9 million[12]). The number of lines in the warehouse almost doubled to 4,572.

With the shift to DCB, the SSA fill rate at Fort Knox improved from 41 percent to 63 percent (see Figure 4.9). Though satisfaction also improved, most of the SSA fill rate increase was the result of a higher accommodation rate. Median CWT for high-priority demands collapsed from two to three days to the same or next day (essentially the document date to SARSS establish time required for customers to get requests into the SSA, as more than half of all requests were filled

Figure 4.9
Fill, Accommodation, and Satisfaction Rates at Fort Knox Before and After DCB



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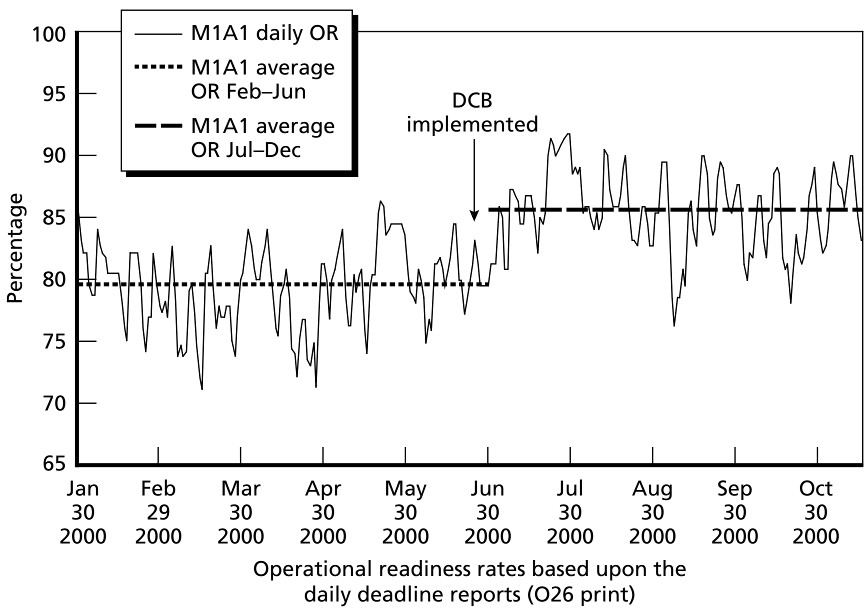
[12] Most of the very-high-dollar lines that drive the inventory value were kept at the same levels.

by the supporting SSA). The 75th percentile of CWT dropped from seven days to just one day.

Improved SSA fill rate and reduced CWT led to an increase in the operational availability of the M1A1 fleet, as shown in Figure 4.10. With similar OPTEMPO and failure rates in both periods before and after the ASL review with DCB, the M1A1 fleet readiness was increased by seven points (or a 33 percent reduction in the not mission capable (NMC) rate).

One of the reasons for the readiness improvement was an increase in the percentage of repair jobs that could be completed with all the requested parts filled from the SSA. When all parts needed for a job are stocked in the supporting SSA, repairs can be completed more quickly because no parts need to be requisitioned from off post.

Figure 4.10
Improvements in Daily Operational Readiness Rates at Fort Knox After the Implementation of DCB



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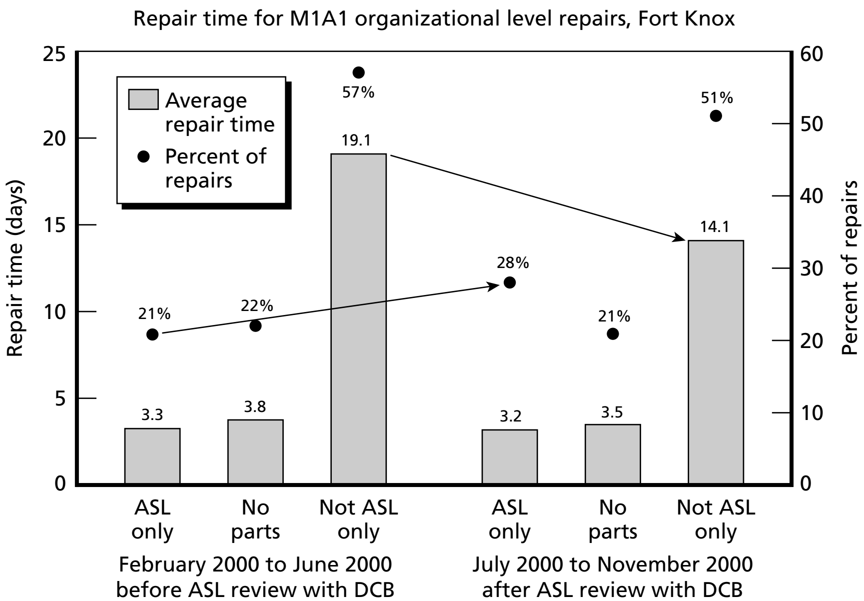
At Fort Knox, the average repair time for jobs completed with all SSA-supplied parts was just three days, while jobs requiring at least one part from an off-post source averaged more than two weeks. After the implementation of DCB, the percentage of jobs at Fort Knox that could be completed with all SSA-supplied parts rose from 21 to 28 percent: a 33 percent improvement (see Figure 4.11).

The percentage of jobs requiring at least one part from an off-post source fell from 57 to 51 percent. Many jobs that in the past would have required several parts from off post now could be completed with only one part from off post. Since CWT for parts from off post exhibit greater variability, the total time spent awaiting parts for jobs with at least one part from off post was also reduced, from 19 days to 14 days. Overall, the average repair time for M1A1 tanks at

Figure 4.11
Decrease in Repair Time at Fort Knox After the Implementation of DCB



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Fort Knox decreased from 12.4 days to 8.8 days, a 29 percent decrease. This reduction translates directly to more available days and higher daily readiness rates.

As this chapter has shown, DCB has led to improvements at both light and heavy units and in nondeployable SSAs supporting high OPTEMPO. In Chapter Five, we will discuss the Armywide adoption of the DCB algorithm for ASL reviews.

CHAPTER FIVE

Armywide Implementation

RAND Arroyo Center has assisted many Army units in conducting ASL reviews using DCB. After two successful uses of the DCB algorithm in ASL reviews in the 101st AA and the 3rd ID, efforts were initiated to expand the use of DCB for ASL reviews across the Army. DCB has also been incorporated into Army policy.

The application of DCB in ASL reviews Armywide has been pursued through a four-part strategy coordinated by the Velocity Group and the SD PIT. First, the Combined Army Support Command (CASCOM) VM cell and the Army G-4 used the SD PIT to modify Army policy to allow for the use of the DCB algorithm in ASL reviews. Second, Arroyo was directed to assist units and expand the use of DCB in ASL reviews as rapidly as possible. Third, the DCB logic was added as a module to ILAP so that organizations Armywide could execute ASL reviews with DCB. Fourth, Arroyo continued its research to improve the DCB algorithm.

DCB Approval as Army Policy

Significantly, DCB has been incorporated into Army policy. On October 12, 2000, the Army policy covering ASL reviews was modified to add DCB as an optional approach for computing inventory recommendations for ASL reviews. The changes were made to the Army's ASL policy in an update to AR-710-2, which stated that "DCB is another HQDA approved alternative ASL stockage deter-

mination methodology" for computing inventory level recommendations for an ASL review. The policy change eliminated the need to seek an exception to policy each time Arroyo worked with a unit to do an ASL review using DCB. On November 4, 2002, the Army policy was modified again, this time making the use of DCB mandatory to determine ASL recommendations. Thus an exception to policy is now needed to use an approach other than DCB.

DCB Implementation

RAND Arroyo Center has helped many units to conduct an ASL review with DCB. The initial "engagements" typically involved a site visit to help the unit redesign storage and workflows in the SSA, similar to those described in this report. The site visits usually included a briefing that documented supply system performance for the organization over the prior two years and that presented a resource-versus-performance tradeoff curve based on the five alternatives covering a range of investment and storage constraints. Because Arroyo was already receiving the document history files from many of the CTASCs across the Army (see Appendixes A and B), it could develop ASL recommendations remotely.

When reviewing the recommendations, most units focused on high-dollar and high-cube items. Supply managers would sort the review file generated by the DCB algorithm, accepting almost all the recommendations for small inexpensive items. Because a mistake on a small, cheap item has little consequence (unlike a mistake on an expensive item), supply managers focused their review efforts on items that consumed the majority of the investment or storage resources. The degree to which local supply managers modified the recommendations varied from unit to unit.[1]

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[1] Some units did not implement any of the recommendations. The most common reasons given were a lack of funding or concern over the number of lines that would result. The latter concern was also related to a lack of high-density storage aids capable of efficiently increasing the number of storage locations in the warehouses.

Units have found that the second and subsequent iterations of DCB are easier to implement. Most of the units that had already used DCB in an ASL review had by necessity already redesigned their warehouse storage and work flows.

Overall during this prototype period, Arroyo was able to generate recommendations with DCB and work with local supply managers to post ASL changes to 29 (covering six divisions) of the 47 SSAs in the 10 active Army divisions (with most of the 29 SSAs doing multiple ASL reviews). The six SSAs of the 1st Cavalry Division (1st CAV) posted a subset of the Arroyo recommendations. Likewise, Arroyo assisted 27 of 78 active nondivisional SSAs including armored cavalry regiments and separate brigades in using DCB in at least one ASL review. Changes were also posted for three TRADOC installation SSAs (e.g., Fort Knox) and four SSAs at the National Training Center.

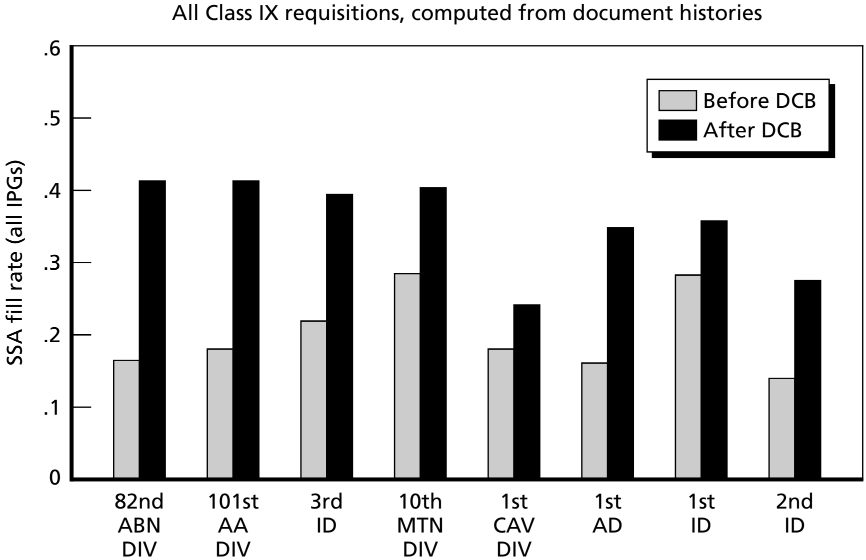
Implementation of DCB in ILAP

Simultaneously, the Army worked with Calibre to integrate the DCB methodology in ILAP, and by April 2001 a version of DCB was available for units to use in ILAP. By necessity there were some changes made to the logic to accommodate the Oracle-based structure of ILAP. In August 2002, some changes requiring little in the way of recoding were made to the ILAP version of DCB to more closely align with the Arroyo version.

Improved Performance Across the Army

Figure 5.1 shows the results for eight Army divisions using actual data (i.e., not simulated) both before and after recommendations derived by DCB (either by Arroyo or through ILAP) were posted. The "Before DCB" period refers to the six months prior to the first ASL review done using DCB, while the "After DCB" period refers to the six

Figure 5.1
Fill SSA Rates for Divisions Before and After ASL Reviews with DCB



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months following the last ASL review using DCB. In some cases, analysis of the ABF revealed that the local supply managers accepted and posted so few of the DCB recommendations that some SSAs effectively cannot be considered to have executed an ASL review using DCB.

The results in Figure 5.1 reflect different levels of success. The best performance has been in the XVIII Corps divisions (the four leftmost divisions in Figure 5.1), which were the first to use DCB in ASL reviews. As a result, all of the XVIII Corps divisions have completed at least two ASL reviews using DCB. Due to budget constraints and limits on warehouse locations, units tend to increase performance in increments. Also, after having already been through the process and seen the results, local supply managers tend to be more likely to follow the recommendations in subsequent iterations.

Local supply managers at the 1st CAV accepted and posted a limited number of recommendations from an Arroyo-generated re-

view file. The 1st ID used ILAP DCB. The 2nd ID has posted both Arroyo recommendations and later improved performance further using the ILAP implementation of DCB.

Along with the SSAs in the divisions, many nondivisional and nontactical SSAs have conducted ASL reviews using DCB.

Continuous Improvement

Throughout the prototype period, the DCB algorithm was refined and significantly improved. The experience to date has suggested two major additional areas in which DCB can be improved.[2]

First, the recommendations of DCB need to be better linked to weapon system readiness. Sites like Fort Knox that have very high OPTEMPO showed clear correlation between improved ASL fill rates and readiness. Other sites showed reduced workaround rates. All sites showed uneven benefits across weapon systems. To better tailor the ASL to support readiness, Arroyo is linking the DCB logic with the data on requisitions for parts needed to complete maintenance jobs to return inoperable equipment to mission-ready status. These data are available through the Equipment Downtime Analyzer (EDA).[3] The EDA saves, integrates, and analyzes data collected by existing standard Army information systems in order to provide a systemwide view of how much each process and organization contributes to equipment downtime. The EDA can pinpoint those places where improvements would make the most difference in equipment readiness. To better link the DCB recommendations to readiness, the

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[2] Many areas of improvement were identified as feedback on supply performance was compiled and have already been implemented as changes to the algorithm. For example, lower-than-expected satisfaction rates and feedback from supply personnel led to improvement in the depth logic and modified EOQ formula.

[3] Peltz et al., *Diagnosing the Army's Equipment Readiness: The Equipment Downtime Analyzer*, op. cit.

idea would be to improve upon the existing logic[4] of how to identify a "critical" item, then focus budget and mobility resources on readiness drivers.

Second, inventory decisions for Army Materiel Command (AMC)-managed items need to be coordinated across echelons under SSF. To date, almost all units using DCB in an ASL review have chosen the least expensive alternative due to budget constraints. Under SSF MS III, the ASL in tactical SSAs were converted from OMA to Army Working Capital Fund (AWCF) funding. This shift reduced some of the financial barriers to improving ASLs. Arroyo is considering two additions to the DCB logic to address resource allocation under the new funding environment.[5] The first is to compute centralized RO levels at the unit or post level to reduce the overall number of assets and better allocate existing assets for forward positioning. The second is to coordinate inventory levels across echelons based on worldwide availability. In both of these cases the resource allocation would be done to improve overall Army CWT for a limited number of high-dollar lines.

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[4] Essentiality code "C" or "D" or an IPG 1 request.

[5] Requirements would remain unchanged and are based on the demands of the direct support customers of an SSA.

APPENDIX A

Guide to Appendixes: Overview of ASL Review Process

Purpose of Appendixes

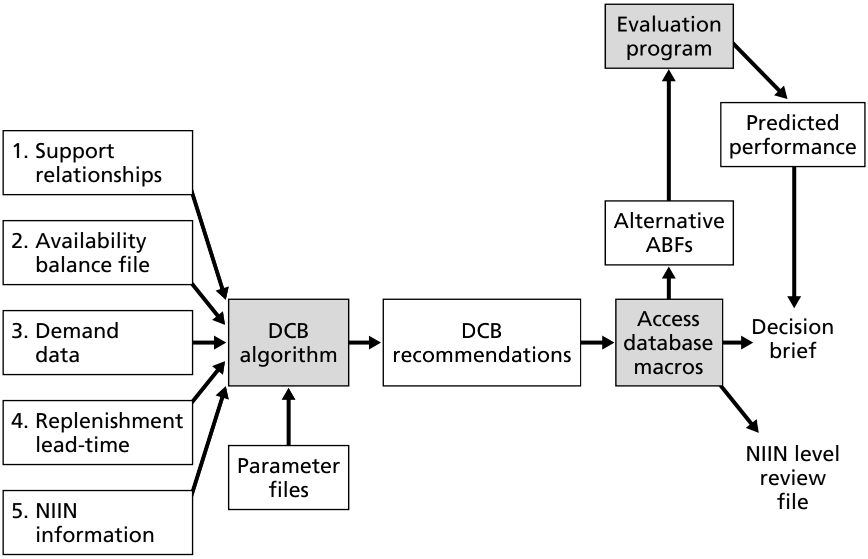
Appendixes A through E are intended to provide technical audiences with a closer look at the use of the DCB algorithm within the context of the ASL review process. The appendixes are designed specifically for readers with a detailed knowledge of and experience in carrying out an ASL review. Such readers will find the appendixes useful for gaining more detailed knowledge of the input files, parameters that control the algorithm output, and how the algorithm works. This should allow those who participate in ASL reviews to better tailor or interpret the results.

This first appendix provides an overview of the ASL review process and serves as a guide to subsequent appendixes, each of which focuses on a different aspect of this process, as described below.

The ASL Review Process

Figure A.1 provides an overview of the process used to conduct an ASL review using DCB during the prototype period of 1998–2000.

Figure A.1
Overview of the Prototype Process Used to Implement DCB



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This process can be described in terms of four major components, each of which corresponds to a subsequent appendix in this report.

- **Input files/support relationships.** The left-hand side of the figure illustrates the primary inputs to the dollar cost banding algorithm: (1) the support relationships describe which customers derive primary support from a given supply support activity (SSA), (2) availability balance file (ABF), which provides a snapshot of the current inventory levels, (3) demand data, (4) replenishment lead time (RLT), and (5) NIIN information. The input files 1–5 are derived from files in the supply information system and catalogue data. These inputs are described in more detail in Appendix B.
- **Parameter files.** Another important group of files is the parameter files, which shape the output recommendations of the DCB algorithm. These are further described in Appendix C.

- **DCB algorithm.** The DCB algorithm uses the various inputs to generate a set of recommendations, which will subsequently be input into an Access database. The algorithm is described further in Appendix D.
- **Simulation and generation of stockage alternatives.** As the DCB recommendations are input into the Access database, a set of constraints is applied to produce five alternative ABFs. The performance for each alternative is estimated using simulation, and a tradeoff curve of performance versus inventory investment is generated to guide decisionmakers. The performance data are combined with mobility and investment information to build a decision brief for local supply managers and logistics leadership. This part of the process is described in more detail in Appendix E.

The ASL review process using DCB is designed to improve the Army's traditional stockage determination process (shown in Figure 3.1). While the use of the DCB algorithm most directly affects steps 1 through 3 of that process, it was designed to make steps 4 and 5 easier as well. Preparation for the ASL review process typically includes the following actions:

1. Determine which SSAs will be included in the ASL review.
2. Identify source of funding for any increases or additions to the ASL.
3. Identify funding or cube constraints to be applied during the review (the latter may involve a redesign of ASL storage and workflows in the warehouse).
4. Review DCB parameters (see Appendix C). A series of parameter tables have been developed to reduce the manual effort during the review of DCB recommendations. Some of these parameters must be reviewed to ensure that they are set appropriately for the SSAs being reviewed; others are system/policy set and are provided for information only.

APPENDIX B

Input Files/Support Relationships

This appendix describes the primary data inputs derived from standard Army supply information systems and the processing of that data required to run DCB. The appendix is necessarily detailed, describing specific data elements. Hence, it will be of most interest to those with a working knowledge of the Army's supply information systems and the data archived from those systems. Those readers can focus on the business rules and processing of the data to better understand how daily supply transactions drive the output of DCB. Readers less familiar with the details of the Army supply system, but who are intimately involved in the ASL review process, should focus on the overall data flows and types of input data used. By better understanding the inputs described in this appendix, those involved in the ASL review process can better understand the output of DCB.

The DCB algorithm is very data-intensive; thus an extensive suite of code was developed to process the data pulled from the CTASC document history files. The supply system data is used to create five primary files, numbered 1–5 in Figure A.1 of Appendix A. The files are:

1. Customer support relationships, describing which customers are supported by each SSA;
2. Availability balance file (ABF), which provides information about existing inventory levels (e.g., RO and ROP for each NIIN);
3. Demand data, i.e., document-level demand data;

4. Replenishment lead time data, which are used to compute the delay from the time the ROP is penetrated until a replenishment arrives by NIIN; and
5. NIIN-level information from the catalogue.

These files become inputs to the DCB algorithm. Each of the files is imported into the Access database along with the DCB recommendations (algorithm output). By making it possible to easily query the input files in a relational manner, it is easier to understand the output of DCB and review the algorithm's recommendations. While reviewing the DCB recommendations, it is useful to have access to the actual demands, replenishment lead times, and item characteristics. Standard drill-down screens in ILAP provide a similar capability for local supply managers.

Each of the input files is described in more detail below.

1. Customer Support Relationships

The customer support relationships establish which customers (identified via their DODAAC) are supported by a given SSA (identified via its RIC). The SARSS DoD Activity Address File (DODAAF) is used to establish the support relationships which are specified by class of supply. The SARSS DODAAF file can change over time. However, the current SARSS DODAAF file is used at the time of the DCB run. Regardless of what SSA supported a customer at the time of a demand, for the purposes of the current ASL review, all demands for a customer are aligned with the current supporting SSA. For example, if DODAAC "X" was supported by SSA "A" for the last two years and then gets reassigned in the SARSS DODAAF as being supported by SSA "B," an ASL review for SSA "B" would include all the demands for DODAAC "X," and an ASL review for SSA "A" would not include any of the demands.

2. Availability Balance File (ABF) Processing

The ABF provides information about existing inventory levels. Knowing the current inventory levels for each NIIN is essential to determine the action to be taken. For example, the add and retain criteria are different depending on whether an item is already stocked or not (this reduces the amount of churn in successive ASL reviews). The input file for DCB includes all records from the SARSS ABF file for which:

- There was a stock level or retention level
  Q_RO>0 *or* **Q_RET>0**[1]
- *and* the stockage codes and ownership purpose codes are not blank
  OWN_PURP NE ` ` *and* **STKG_CD NE ` `**
- *and* the condition code indicates a record for a serviceable item
  COND_CD = 'A' *or* **'B'** *or* **'C'**

Each NIIN in the file is rolled to the prime NIIN using order of use (OOU) and phrase code data. If there are multiple records for a prime NIIN, the values are rolled up as follows: sum the due in and due out and take the largest **Q_RO** and **Q_RET**. If the record in the actual ABF was not under the prime NIIN, the code creates the necessary transactions that when processed will add a record to the ABF under the prime and delete the record in the ABF associated with the old NIIN.[2]

The file input to the DCB algorithm has the structure shown in Table B.1. The DCB algorithm itself uses only the NIIN, RIC, RO, ROP, SCODE, and YEB fields. The program extracts data for all the RICs to be included in the DCB run.

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[1] Field names from the files are presented in bold. Logical conditions are presented in italics.

[2] As units have used the process described in this report to do an ASL review, this problem typically goes away or the number of such records is much smaller.

Table B.1
Structure of the File Input to the DCB Algorithm

NIIN	RIC	RO	RP	SL	RET	OH	DISOS	DIMT	DIRET	DO	SCODE	IP	YEB
000782908	AMX	455	303	0	0	0	564	0	0	112	M	454	*****
000782908	WQT	150	100	0	0	26	78	0	0	0	M	104	*****
000867792	WQR	2	1	0	0	2	0	0	0	0	M	2	*****

Where:

NIIN = identifies the item with the nine-digit national item identification number.

RIC = identifies the SSA with the three-digit routing identification code.

RO = requisition objective.

ROP = reorder point.

SL = safety level, which is a subset of the ROP.

RET = retention level, the number of assets above the RO that can be retained in the SSA and drawn down in place by demand without the need to redistribute (due to turn-ins or a decrease in the RO during an ASL review, the inventory position occasionally exceeds the RO).

OH = the current on-hand serviceable assets.

DISOS = due in source of supply is the assets requisitioned but not yet received from higher up the supply chain.

DIMT = due in from maintenance, number of unserviceable assets job ordered to direct support maintenance.

DIRET = Assets due in as returns from customers (e.g., unmatched repairable items).

DO = due out, the total quantity owed by the SSA to fill outstanding customer requests.

SCODE = stockage code; the Army uses a one-position alphabetic code that indicates the reason for stocking specific items.

IP = inventory position, sum of on-hand plus due ins minus due outs.

YEB = taken from a field that records the last time a transaction (these transactions have a document identifier code of "YEB") changed this record in SARSS ABF file.

Order of Use Processing

As engineering changes or technology updates are made, occasionally older NIINs are replaced by new NIINs, referred to as the prime. Where several NIINs work for the same function or repair, the preferred NIIN will be labeled the prime. Keeping track of these interchangeability and substitution relationships across all NIINs used by a typical Army unit is a critical part of the ASL review process. The translation from old to prime NIINs uses the current order of use information obtained from FED LOG disk 3/data/oou.txt.

The file layout includes the prime NIIN in positions 12–20 and a substitute NIIN in positions 52–60. There is a record for each prime-substitute relationship (including the prime with itself) for any active NIIN with substitutes. During file processing, all substitute NIINs are replaced with their primes.

Phrase Code Processing

Replacing NIINs with their phrase substitute involves finding a valid NIIN for those NIINs that can no longer be ordered from the supply system. NIINs that can no longer be ordered from the supply system are identified with a missing acquisition advice code (AAC) or phrase code among the following: A, C, D, E, F, L, T, and Z. The valid replacement NIIN is selected by parsing the phrase statement for the first numeral, keeping the next 11 characters after that, and removing '-'s from the NIIN. If a phrase replacement is a NIIN for which catalogue data was not obtained in the initial pull of catalogue data, then another run including this FED LOG information will be appended to the first (since the phrase code substitution is not known when the initial run to get catalogue data is made, this can become an iterative process). During file processing, all phrase substitutes are replaced with their "primes."

3. Demand Processing

The third input file provides document-level[3] demand data used in the iterative simulation methodology used by DCB to set the depth (e.g., RO and ROP for a given NIIN). As described in the customer support relationships, customers are identified via DODAACs, which are assigned to the RICs of the supporting SSA. All demands are associated with customer or DODAAC. Hence, if a customer-to-SSA support relationship changes, the entire demand history of the customer will go with the DODAAC and be assigned to the new RIC. This also allows for the rapid configuration of ASLs during deployments if customer support relationships are changed, as long as the changes occur at DODAAC (typically company) level. Changes below the company level (e.g., reassigning a few weapon systems from one company to another), common when task forces are assembled for specific missions, are not as easily handled.

Customer requests are taken from the SARSS header file. A record is established in the header file when the first instance of a unique document number occurs. Records with the first two digits of the three-digit document identifier code (DIC) equal to **'A0'** *or* **'A5'** *or* **'AT'** *or* **'AE'** are selected as demands. These are records associated with the initial customer request or a follow-up of the customer request. In some cases, there were issues to customers without the existence of a header record. So the code also checks the SARSS issue file for DIC = **'A5A'** *or* **'A51'** *and* **mgrcdmro = I** *or* **B** to identify demands without a header record. These are assumed to be valid customer requests and are included using the sum of the quantity issued across suffix codes on a document.

Under SSF, or in any circumstance in which the SARSS process referred to as RON/DON (request order number/document order

[3] Document-level data imply that information from the original customer request is used to determine the NIIN, quantity, day of the request, fund code, project code, and priority—that is, all the information that would be required to simulate the supply system if different inventory levels had been in place.

number) is turned off and the issue is not seen, the first condition identifying a customer request via the header record will still work. We have verified that this continues to work after conversion to single stock fund.

The output file lists each customer request and the maximum quantity requested for cancellation on any one cancellation request (DIC = 'AC1' from the status file). In subsequent processing, a document counts as a demand only if the requested quantity is greater than the requested cancellation quantity.

Largest cancel quantity is used instead of a sum because cancellation ineffectiveness often led customers to resubmit cancellations several times (we do not have information in the subset of the status file we receive on confirmation of cancellations). Empirical analysis of documents with multiple cancellation requests showed the sum of requested cancellation quantity was frequently more than the original requested quantity, and in most cases there was still an issue to the customer with quantity equal to the requested quantity minus the first cancellation request.

Issue priority group (IPG) is assigned based on the priority designator field in the header file. IPG 1 is priority designator 1 through 3, IPG 2 is priority designator 4 through 8, and IPG 3 is priority designator 9 through 15. If there is no priority designator in the header file, or no header record, the IPG is assumed to be 3.

Table B.2 shows the output of the demand tables listing each demand for a given SSA. The demand summary file also includes RDD and the Dmdsfxcd fields from header records. The Dmdsfxcd field identifies recurring versus nonrecurring demands.

Table B.2
Output of Demand Summary File

DODAAC	JDATE	NIIN	DMDQTY	CANQTY	IPG	SSA	SEQNO	RDD	EIC	DIC	RQNREC	RECUR
W51HQS	1998015	000011549	300	0	2	BXN	5003			A0A	98021	
W51HQS	1998090	000011549	200	0	3	BXN	0002			A0A	98103	
W51HQS	1998134	000011549	150	0	3	BXN	4000			A0A	98139	

Where:

DODAAC = DoD activity address code; each customer of the SSA has a unique DODAAC.

JDATE = Julian date from the document date contained in the document number of the original customer request.

NIIN = national item identification number of the item requested.

DMDQTY = typically taken from the quantity field in the header file; this is the quantity requested by the customer on the original request.

CANQTY = as described above, this is the maximum cancellation quantity from all the cancellation requests in the status file for this document number.

IPG = issue priority group.

SSA = the RIC of the supporting SSA (derived from the current SARSS DODAAF file).

SEQNO = the last four digits of the document number, which make each document number unique.

RDD = required delivery date, typically used to identify critical requests or delayed shipping instructions.

EIC = from the distribution code field in the SARSS header file, the end item code identifies the type of weapon system that is unavailable as a result of this part request.

DIC = document identifier code on the record used to establish this demand.

RQNREC = this is typically the establish date in the header file that represents the date the customer request was passed to SARSS. (The time required for the customer to get the request to SARSS can then be computed as RQNREC – JDATE).

Recur = field from the header file used to flag whether a request is recurring or not. Some requests are nonrecurring,

i.e., exceptional and not expected to recur again. Nonrecurring requests are not included in the computation of inventory levels. No entry or an "R" in this field is taken as a recurring demand. An entry of "N" implies the demand is nonrecurring.

Filtering Request Quantity Outliers from the Demands

The purpose of this analysis, which acts on the demand file described above, is to stop outlier request quantities from driving the RO and ROP values set using the DCB logic. Our analysis of the empirical data showed some extreme outliers in terms of the request quantity. Analysis showed numerous examples in which the predominant request quantity was in the single digits and one request in which the quantity requested was in the thousands or tens of thousands.

The robust estimation literature has proposed box plots and outlier rules related to the box plots.[4] Let q75 be the 75th percentile and q25 be the 25th percentile. Their difference iq = q75 – q25 (called the interquartile range) measures the range of the middle half of the data. A very small fraction of the data is expected to be more than 1 or 2 iq's beyond this range. By convention, "inner fence" outliers are defined as q75 + 1.5 * iq or beyond; "outer fence" outliers are defined as q75 + 3 * iq or beyond. Inner fence outliers occur with probability 0.0035 for data from a normal distribution; outer fence outliers have probability 0.0000011.

Having looked at the historic demand streams for several NIINs, we chose to truncate large outliers to the outer fence for use in computing the inventory levels. Empirical experimentation shows that this approach performs well. Because of the extreme skewedness of the request quantities, we first took the square root of the demand quantity before applying the fencing algorithm. Then, after Winsorizing, we squared the transformed value.

The "final" algorithm:

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[4] See, for example, William Mendenhall and Terry Sincich, *Statistics for Engineering and the Sciences, 4th Edition*, Englewood Cliffs, N.J.: Prentice-Hall, 1995.

1. Unit of observation is the document number (in the file demand).
2. Fields include quantity demanded and quantity cancelled.
3. Net quantity = demands minus cancellation.
4. To do this, look at all demands for a given NIIN over the review period (this is a NIIN, not a RIC/NIIN, computation).
5. Compute the 25th percentile of net quantity: call it nqty25.
6. Compute the 75th percentile of net quantity: call it nqty75.
7. If nqty75 and nqty25 have the same value, set nqty75 = nqty75 + 0.5 and set nqty25 = nqty25 – 0.5.

With this adjustment:

outer fence = sqrt(nqty75) + 3 * (sqrt(nqty75) – sqrt(nqty25)) and

nqty = min(net quantity, outer fence * outer fence).

The squaring of the outer fence in the last formula compensates for the fact that the Winsorizing was done on the square root. If the quantity is greater than outer fence squared, it is set equal to outer fence squared. Effectively, these demand quantities with extreme outliers "clipped" to the outer fence squared are input to the DCB algorithm for the computation of the recommended RO and ROP values.

When performance of the recommended RO and ROPs is computed, the original request quantity is used. In the case of quantities filtered as above, that will typically empty the shelf and cause a backorder.

4. Computation of the Replenishment Lead Time

A critical element of the computation of inventory levels is the time needed to restock an item in the SSA after the inventory position of the item reaches or goes below the ROP, and a replenishment requisition is generated. The delay is often referred to as the replenishment lead time (RLT) and, along with the arrival of demands, is a critical

element in setting lead time demand. The ROP[5] is then set to fill the lead time demand, to a given level of confidence, while avoiding backorders.

RLTs in DCB are set at the RIC/NIIN level using the 75th percentile of all receipts with the following DICs: D6K, D6S, *or* D6M) and where the **cond_cd** is A, B, or C (i.e., a serviceable asset is receipted by the SSA). We use all priorities and include backorders to keep the population sizes up. When there are still insufficient receipts to build a reliable estimate of RLT (< 10 valid receipts), which is often the case, then RIC level results are also utilized via a weighted average (see formulas below). To be included in the computation, transactions must have been completed (a receipt processed), so outstanding due ins are not included.

Consumables (nonreparable) are treated differently from reparables (determined by a maintenance repair (MR) code of F, H, D, or L), which may have multiple sources of supply. The formula below applies to nonreparable items:

n2 = number of D6_ receipts.

ostw75 = the 75 percent of the RLT for valid D6_ receipts for the specific NIIN (receipt date – document date).

tostw75 = the 75 percent of the RLT for all valid D6_ receipts at the RIC (receipt date – document date).

maxost = maximum value of ostw75 allowed, typically set at 45 days.

The value 10 in the formulation below is also a parameter, and it determines the number of valid receipts at the RIC/NIIN level needed to avoid using a weighted average.

The weighting formulas follow:

replen1 = int(((min(n2/10,1))*(min(ostw75,maxost)))

[5] The difference between the RO and ROP, or order quantity, determines how often the item will approach the ROP (e.g., the number of times per year there is a danger of stocking out).

+ (max((1 – (n2/10)),0)*tostw75)).

For reparables the formula is more complicated, owing to the potential of repair as a source of supply. There is no weighted average across repairs of all NIINs (since each NIIN may go through a different repair process); rather, the repair transactions are weighted in the formula above. There is also a minimum value enforced as below:

replen2 = max(mx_,replen1).

For deployable units we have set the value for mx_ at 10 days, while for nondeployable units 5 days may be used.

The output of the replenishment lead time code is a file called ost.csv, as shown in Table B.3. This file contains replenishment lead time for every RIC/NIIN. Receipt times for all D6S receipts (across all NIINs) for a given RIC are computed internally and used in the computations. The key outputs are shown in Table B.3. The key fields are RIC, NIIN, and replen; the other fields are output for information purposes only.

Table B.3
Output of Replenishment Lead Time

RIC	NIIN	REPLEN	REPLEN (UNMAXED)	MRC	TOTALN	TOTMEAN	TOT75%	D6SN	D6SMEAN
WGT	000782908	36	36	1	134	39.85821	35	68	51.07353
WH1	000782908	31	31	1	39	33.23077	53	22	49.90909
WCH	000782908	36	36	1	101	68.90099	76	33	132.6061

D6S75%	DSKN	DSKMEAN	DSK75%	D6MAN	D6MAMEAN	D6MA5%	D6MFM	D6MFMEAN	D6MF75%
35	16	12.375	13	50	33.4	41	30	23.76667	26
66	17	11.64706	13	0		0	0		0
139	68	37.98529	32	0		0	0		0

Replenishment lead time (unmaxed) is reported so we can gauge how many RIC/NIINs are getting replenishment lead times of less than 10 days (recall we use the maximum of 10 days and the computed replenishment lead time for deploying units). The other fields are values used internal to the replenishment lead time computation

as the associated "n" and "75%" (mean is also given in the file so we can get an idea of the impact of outliers).

5. NIIN Information Processing

The DCB algorithm makes use of NIIN-level data like unit price, unit cube, and acquisition advice code (AAC) in setting the recommended inventory levels. NIIN-specific data are pulled from the most recent FED LOG file. Information is pulled for each NIIN that has either had a demand, issue, receipt in the last two years, or a record in the most recent SARSS ABF file. The NIIN information file is built using the most current set of FED LOG disks, which are loaded on a UNIX workstation. The new FED LOG is usually received and loaded before the 15th of the month. Occasionally, we experience problems with the batch processing code. These errors have been reported to software support and seem to indicate a problem in compiling code before the software is shipped. Fields are selected for Service = Army from the AMDF portion of the data. Two passes through the FED LOG may be required to get all valid NIINs (due to phrase code substitutions; see above). The first pass gets all information, including phrase code substitutions, for NIINs. The second pass gets information on additional NIINs only seen as phrase substitutions. These two parts are appended together in the final output. This processing takes place through the UNIX batch processing utility on FED LOG CD 1 (1/tools/sun/runbatch with and without a trailing period depending on the month) and runs a job file designed through the interactive batch design program (see below). The file is called by identifying the job file and location of CDs, and it contains redirection of systems error output.

Item-level information on prime NIINs is output to the NIIN information file. Note that OOU and phrase code substitutions impact all files' output (all information on nonprime NIINs is rolled to the prime in the input files for the DCB algorithm). The file has the structure shown in Table B.4.

Table B.4
Structure of the NIIN Information File

FSC	NIIN	MR	RC	MATCAT	SOS	ARI	EC	AAC	SCMC
6505	000000073		0	1					
5310	000000079	Z	M	C	S9I		C	D	9T
5330	000000085	Z	0	0	S9I		G	J	9T
4730	000000086	Z	0	0	S9C		G	Z	9B

UPRICE	NOMEN	WEIGHT	CUBE	UPQTY	ARC	UI	PHRASE CODE	PHRASE STATEMENT
	Inactive–deleted							
$0.15	Washer, flat	1	1	001	X	EA		
$29.08	Retainer	1	1	001	X	EA		
$4.19	Reducer, tube				X	EA		

Where:

FSC = federal supply class.

NIIN = national item identification number, for primes only.

MR = maintenance repair code, identifies the level of repair for a NIIN. The code that computes the replenishment lead time uses the MR field to determine whether to use the consumable or reparable replenishment computation (this must be done because a RIC/NIIN may have only D6S and D6K receipts, and it is not immediately obvious which formula should be used). Even if there are D6M receipts, we will use the consumable formula if the MR code implies the item is not a reparable.

RC = recoverability code.

MATCAT = materiel category code; if an item is used predominantly on a single weapon system, the MATCAT identifies the weapon system.

SOS = source of supply; this is the RIC of the national-level manager of the item.

ARI = automatic return item; identifies NIINs that should be immediately returned to a repair site.

EC = essentiality code; engineering determination whether the item is essential for operation of a weapon system(s). This field is used in the DCB add/retain logic.

AAC = acquisition advice code; this code identifies obsolete items and items that have various restrictions (it tells the customer how to get an item). Used in DCB parameter files (see Appendix C).

SCMC = supply class materiel code. First character is used in DCB parameter files (see Appendix C).

UPRICE = unit price; the add/retain criteria and CWT goals used in DCB are a function of unit price.

NOMEN = nomenclature, which is a description of the NIIN.

WEIGHT = weight of the NIIN in tenths of a pound.

CUBE = cube of the NIIN in thousands of a cubic foot; unit cube restrictions can be set.

UPQTY = unit pack quantity, the quantity in which a NIIN is typically packed and shipped from regional distribution centers.

ARC = Accountability requirements code; NIINs with an ARC of "N" are not allowed on the ASL (see Appendix C).

Phrase code and phrase statement is used to identify a substitute NIIN for NIINs that can no longer be requisitioned from the wholesale system.

APPENDIX C
Parameters

This appendix describes the DCB parameters. The parameters are set through a series of input files to the DCB algorithm. This appendix will be of interest to those who participate in the ASL review process. Users must edit some of the parameters to tailor solutions for specific SSAs.

The parameters have two purposes. The first is to set input values required to run the DCB algorithm, for which it was desirable to have a simple way of changing values. These parameters are referred to as "system parameters." The values of system parameters are set by Army policy and cannot be changed without coordination with the CASCOM Distribution Team and Army G-4 Supply Policy Branch. Examples of system parameters are the number of demands required to add or retain an item on the ASL or the unit price range at which the different add/retain values apply. Another example is the CWT goal by unit price.

The second purpose of the parameters was to address many of the tasks typically done manually during an ASL review. As the SD PIT team walked through the ASL review process, common themes or decisions occurred across different types of organizations as local supply managers and others involved in the ASL review process reviewed the recommended RO and ROP levels. By capturing the information needed to make these decisions in parameters and coding the logic used, it was possible to both improve the quality of the DCB output and make the ASL review process more efficient. These parameters are referred to as "user parameters." While a standard set

of user parameters stored in files has been developed, before initiating an ASL review, local supply managers and those participating in the ASL review process should review the user parameter files. For example, the user parameters can be used to automatically identify and screen out nonessential, bulky, and cosmetic items by screening out NIINs with certain federal supply classes or nomenclatures. For example, the parameters and associated logic may act to override add/retain logic that is based only on the number of demands. Not all the decisions made during a typical ASL review are captured in the user parameter files, so review of the DCB output by local supply managers is still a critical part of the ASL review process.

System Parameters

The values of system parameters are typically controlled by the Army G-4 and are driven by policy-level decisions.

1. A "cost" band is a range of unit price. Each NIIN falls into one cost band. There can be as many cost bands as desired. Each cost band can have a different CWT goal and, along with other criteria (see below), add/retain criteria. Table C.1 shows an example with four bands.
2. The add/retain criteria may be set differently based on the characteristics related to the NIIN (class of supply and essentiality code), the demands for the NIIN in the review period (high priority or not), type of SSA, the application of the NIIN (low density or not), and the cost band. Table C.2 shows an example.

Table C.1
Definition of Cost Bands and Associated CWT Goals

Unit Price	Band	CWT Goal
$0 through $10	1	1.3
$10.01 through $100	2	1.5
$100.01 through $1,000	3	1.7
More than $1,000.01	4	2.0

Table C.2
Add/Retain Criteria

Type SSA	Class	e-code	Low Density?	IPG 1 Demand?	Band $0–10 Add	Band $0–10 Ret	Band >$10–100 Add	Band >$10–100 Ret	Band >$100–1,000 Add	Band >$100–1,000 Ret	Band >$1,000 Add	Band >$1,000 Ret
AVN	9	C D E F .	NA	NA	4	2	6	2	6	2	6	2
AVN	9	G J . . .	NA	YES	6	2	6	2	6	2	6	2
AVN	9	G J . . .	NA	NO	24	6	30	6	60	6	1d9	6
DOL	9	C D E F .	YES	NA	4	2	6	2	6	2	6	2
DOL	9	C D E F .	NO	YES	4	2	6	2	12	6	18	6
DOL	9	C D E F .	NO	NO	8	4	8	4	12	6	18	6
DOL	9	G J . . .	NA	YES	4	2	6	2	12	6	18	6
DOL	9	G J . . .	NA	NO	24	6	30	6	60	6	1d9	6
FWD	9	C D F . . .	YES	NA	4	2	6	2	6	2	6	2
FWD	9	C D F . . .	NO	YES	4	2	6	2	12	6	18	6
FWD	9	C D F . . .	NO	NO	8	4	8	4	12	6	18	6
FWD	9	E G J . . .	NA	YES	4	2	6	2	12	6	18	6
FWD	9	E G J . . .	NA	NO	24	6	30	6	60	6	1d9	6
MAIN	9	C D E F .	YES	NA	4	2	6	2	6	2	6	2
MAIN	9	C D E F .	NO	YES	4	2	6	2	12	6	18	6
MAIN	9	C D E F .	NO	NO	8	4	8	4	12	6	18	6
MAIN	9	G J . . .	NA	YES	4	2	6	2	12	6	18	6
MAIN	9	G J . . .	NA	NO	24	6	30	6	60	6	1d9	6

3. Certain nonexpendable items that must be maintained on the unit property book cannot be stored in the ASL even if customer requests have been received. Items with an accounting requirements code (ARC) of "N" cannot be stocked on the ASL regardless of demands.
4. Items with certain acquisition advice codes may not be stocked on the ASL. The acquisition advice code identifies obsolete items and items that have various restrictions (it tells the customer how to get an item). Table C.3 shows the AACs that DCB will not recommend for the ASL, typically because they can no longer be ordered from the national-level supply system.

Table C.3
AAC Not to Be Stocked

F	Fabricate, assemble, or obtain from other source
K*	Centrally stocked for OCONUS only
L	Local purchase
M	Restricted requisitions major overhaul
N	Restricted requisitions disposal
O	Packaged fuel DLS managed and service regulated
P	Restricted requisition security assistance PGM only
Q	Bulk petroleum products DLA-managed
R	Restricted requisition government-furnished materiel
S	Restricted requisition other service-funded
T	Condemned
V	Terminal item
Y	Terminal item
W	Restricted requisitions special instructions apply

* Authorized for OCONUS stockage.

User Parameters

The previous subsections described how the add/retain parameters are set based on the number of demands and unit cost of a NIIN. However, there are criteria other than demand that may cause one to override demand-based criteria. These include:

1. Restrictions may be set on unit cube by essentiality code. Items above a user set value will not be stocked in the ASL.
2. Restrictions may be set on class of supply. For example, the user can set parameters to make sure that Class II materiel is not stocked in an SSA that supports only Class IX. Or that aviation items, class of supply 9A, are not stocked in nonaviation SSAs.
3. Army policy has long allowed for lower add/retain criteria for low-density equipment (which, while still requiring support, will generally have NIINs with fewer demands). However, the NIINs for which these policies apply had to be identified manually. To address this, the low-density parameter table uses class of supply and

the fourth and fifth characters of the MATCAT to identify NIINs for which the lower add/retain criteria associated with low-density equipment apply. An example is given in Table C.4. The effect of a NIIN being classified as low density is reflected in Table C.2, so the low-density parameter is reflected in the demand-based add/retain criteria.

4. Many SSAs stock items that are used only when units deploy but must be held locally so units can quickly deploy (e.g., maps). These items are identified by FSC in a parameter table. Items from the FSCs listed will not be deleted even if there have been no demands in the two-year review period. An example is given in Table C.5. This list must be reviewed to ensure that it includes any specific FSCs that are unique to the local SSAs.
5. In addition, the RO will not be changed or deleted on items that are stocked on consignment from vendors. Table C.6 provides the stock number of consignment NIINs; changes in the levels must be negotiated with the appropriate vendor. This table must be reviewed to ensure that all consignment items are included.
6. There are also large bulky items not related to readiness that should not be stocked regardless of demands. One way of identifying these items is by FSC. These items will not be stocked regardless of the number of demands that occurred during the review period. Examples are provided in Table C.7. This table contains the FSCs that are not normally stocked because of the difficulty in handling; the list should be reviewed to ensure that it does not contain FSCs that the SSA desires to stock.
7. The phase-out list identifies equipment that is being phased out. Although these items are being phased out, demands may be generated while the equipment is being prepared for turn-in. Although the support items may be demand-supported, future demands are not anticipated; thus, the RO for these items will not be increased or added if an RO does not already exist. These items are identified by the 4th and 5th position of the MATCAT, as shown in Table C.8. This table must be reviewed and any equipment that is being phased out must be added.

8. Nomenclatures are also screened to prevent the stockage of cosmetic items (see Table C.9) that do not contribute to readiness. Items with nomenclatures that match this table will not be stocked even if they have sufficient demands.

Table C.4
Identification of Low-Density Equipment Support Items

Class	Matcat4	Matcat45	Description
9A	.	.	Repair parts used on aircraft
9L	.	.	Missile-related repair parts
9Q	.	.	Marine equipment repair parts
.	A	.	Fixed wing aircraft
.	B	.	Rotary wing aircraft
.	C	.	Other aircraft categories
.	D	.	Surface to air missile
.	E	.	Surface to surface missile
.	F	.	Other missile related materiel
.	I	.	Construction equipment
.	U	.	POL, Soldier, and Combat Support Systems
.	Q	.	Avionics
.	.	N8	Pallet loading system (PLS)
.	.	NR	984_Wrecker
.	.	NR	HEMITT
.	.	WL	10K_Forklift
.	.	WL	6K_Forklift
.	.	WL	DV43 RTCH
.	.	NT	936_Wrecker
.	.	LP	Volcano
.	.	LP	MICLIC
.	.	UF	ROPU

Table C.5
Contingency Items Not to Be Deleted

FSC	Description
7641	Aeronautical mapping, charting, and geodetic products
7643	Topographic mapping, charting, and geodetic products
9930	Memorials, cemeterial and mortuary equipment supplies

Table C.6
Consignment NIINs

NSN	Nomen	Type	Source
6140014469506	Battery, storage	6TN	EXIDE
614003901969	Battery, storage	2HN	EXIDE
6140013901968	Battery, storage	4HN	EXIDE

Table C.7
Large Items That Will Not Be Stocked

FSC	Description
7035	ADP supplies and equipment (computer cases)
7105	Household furniture (cots and components)
7195	Misc. furniture and fixtures (tables)
9340	Glass fabricated material
9505	Wire, non-electrical, iron and steel
9510	Bars and rods, iron and steel
9515	Plate, sheet, strip and foil, iron and steel
9520	Structural shapes, iron and steel
9525	Wire, nonelectrical, nonferrous based metal
9530	Bars and rods, nonferrous based metal
9535	Plate, sheet, strip and foil: nonferrous based metal
9540	Structural shapes, nonferrous based metal

Table C.8
Phase-Out Items Identified by MATCAT, RO and Not to Be Added or Increased

NH	2 _ ton vehicle configuration (diesel)
NJ	2 _ ton vehicle configuration (gas)
NK	2 _ ton vehicle configuration (multifuel)
NL	5 ton vehicle configuration (diesel)
NM	5 ton vehicle configuration (gas)
NN	5 ton vehicle configuration (multifuel)
NS	CUCV
JP	Combat engineer vehicle M728
NV	Recovery vehicle M578
ND	1 _ ton vehicle M880 series
JQ	Armored/Reconn/Airborne Assault Vehicle M551

Table C.9
Sample of Cosmetic Items Screened by Nomenclature

BOARD; FLOOR TRAILER	BOARD; SEAT	BOARD; SEAT; RACK
BOARD; SIDE RACK	BOW	BOW ASSEMBLY
BOW CORNER; ASSEMBLY	BOW; SIDE RAIL	BOW; VEHICULAR
BOW; VEHICULAR TOP	BOX; ACCESSORIES STO	COVER EXTENSION
COVER FITTED	COVER FITTED VEHICULAR	COVER; SEAT CUSHION’
COVER SEAT POST	COVER; SEAT; VEHICULAR	CURTAIN ASSEMBLY
CURTAIN; BLACKOUT	CURTAIN; WINDOW	CUSHION ASSY
CUSHION ASSY; SEAT	CUSHION ASSY BACK REST	CUSHION BOTTOM
CUSHION HEADREST	CUSHION SEAT BACK V	CUSHION; CHAIR AND S
DOOR ASSEMBLY; VEHIC	DOOR ASSY; ACFT	DOOR; VEHICULAR
FENDER ASSEMBLY	FRAME TENT EXPAND 8	FRAME; SEAT; VEHICULAR
FRAME; STRUCTURAL; VE	FRAME; VEHICLE COVER	FRAME; WINDOW; VEHICULAR
GLASS LAMINATED FLA	GRILLE; RADIATOR; VEH	GRILLE; VENTILATION
HOOD ASSEMBLY	HOOD ENGINE COMPART	PAN; DRIP

APPENDIX D

DCB Algorithm

This appendix provides a more detailed description of the DCB algorithm. The more detailed description of the qualification logic can be used with the information already presented in Appendixes B and C to give those who participate in the ASL review process a better understanding of the DCB output. The more detailed description of the iterative simulation technique used to set the depth will be of interest to those who code inventory algorithms.

Qualification Logic

The user and system parameters described in Appendix C are used to determine which NIINs qualify for stockage. The algorithm first evaluates whether the NIIN qualifies for stockage based on the appropriate add/retain criteria (see Table C.2). For NIINs that qualify based on demands, the system and user parameters that can override the demand-based logic are checked to determine whether the NIIN still qualifies or has been excluded. The order in which the parameters are checked is important because a flag will be set to alert the user why the item was excluded. The most important exclusion parameters (those least likely to be overridden by the user) are checked first.

For NIINs that do not qualify based on demands, the user parameters that can override the demand-based retain logic are checked to determine if the NIIN must be retained on the ASL. The inclusions are limited to the contingency and consignment parameters (see

Appendix C). Again, if the demand-based add/retain criterion is overridden, a flag is set to alert the user why the item is being retained.

Depth Logic

All NIINs that have had a demand or have a positive RO on the most recent ABF get a recommended RO and ROP. This is important because when reviewing the RO and ROP recommendations, it may be desirable to override the user-set parameters for specific NIINs.

First, a modified EOQ is computed to determine the order quantity. This computation is discussed in detail in Appendix F. Once the order size has been computed, the problem becomes one of computing the reorder point. As outlined in the main body of this document, the DCB algorithm uses iterative simulation and variable (based on unit price) CWT goals to compute the ROP. There are three factors that affect the ROP computed for a given NIIN: (1) the demands and how (timing and frequency) they arrive at the SSA, (2) the RLT, and (3) the unit price of the NIIN (which determines the CWT goal).

The steps of the iterative simulation are repeated for each SSA/NIIN combination.[1] For a typical division with five SSAs, this can involve the computation of over 100,000 RO and ROPs. Each of these 100,000 RO and ROP computations can involve multiple simulations to converge to the CWT goal.

The logic below describes how the ROP is adjusted until the CWT goal is reached.

Step 0. Set counter iter = 0; this is the number of simulations performed to converge to the CWT goal. Compute CWT with RO = 0; if goal is achieved, stop—this item does not need to be stocked on the ASL.

[1] Multiple SSAs can be included in the same DCB run.

Step 1. Initiate the value of ROP(iter) = integer ((5+RLT) * daily demand rate) and RO(iter) = ROP(iter) + MEOQ

Where:

Integer is the integer function that rounds to the nearest integer.

RLT is computed as described in Appendix B.

Daily demand rate is the sum of requisitions quantity in the review period divided by the number of days in the review period.

MEOQ is the modified EOQ .

The ROP computed in the 0th iteration is the same that would be computed using the Army's SARSS demand analysis algorithm. The five represents the constant five-day safety level from Army policy.

Step 2. Execute the simulation to determine the CWT(iter) associated with the RO(iter) and ROP(iter). (See description below.)

Step 3a. If CWT(iter) ≤ CWT* (where CWT* is the CWT goal) and iter = 0, then stop, RO(0) and ROP(0) achieve the CWT goal for this RIC/NIIN.

Step 3b. If CWT(iter) ≤ CWT* (where CWT* is the CWT goal) and iter > 0, then go to step 4.

Step 3c. If CWT(iter) > CWT* (where CWT* is the CWT goal), then increase the value of ROP(iter + 1) = ROP(iter)* 2. Then set iter = iter + 1 and return to step 2.

Step 4. Set iter = iter + 1. A single linear regression is used to try to compute an ROP closer to the CWT goal. If after applying linear regression and computing the value of ROP(iter) using the integer function ROP(iter) = ROP(iter – 1), then stop. ROP(iter) satisfies the CWT goal. Else go to step five.

Step 5. Execute the simulation for ROP(iter). If the returned CWT(iter) > CWT*, then take ROP(iter – 1) as the solu-

tion. If the returned CWT(iter) ≤ CWT*, then take ROP(iter) as the solution. Stop.

The simulation used to compute the CWT associated with each set of RO and ROP values for a given RIC/NIIN involves four key steps: (1) initiating the inventory position (IP) at the outset of the simulation as IP = ROP + integer[½*(RO – ROP)], (2) tracking the daily inventory position in terms of on-hand, due in, and due out assets as each demand from the two-year demand history is processed and replenishments arrive, (3) initiating a replenishment when the IP < ROP of quantity RO – IP that arrives RLT days later, and (4) track the CWT for each demand processed. A more detailed description follows below:

Step 1. Set t = 0 and initiate IP(t = 0) = ROP(iter) + integer [½*(RO(iter) – ROP(iter))] where the iteration counter, iter, is for a given RIC/NIIN and is the iteration counter described above. Set the variable CWT, which is used to sum the total number of days of delay over all requests for this RIC/NIN, equal to 0.

Step 2. Set t = t + 1, if there are no outstanding due outs at time t (i.e., Y = 0) and there are no more demands to be processed (X = 0, for all time > t), then go to step 7. Else, set OH (t) = OH (t) + DI (t). Set the number of demands on day t equal to X. Set the number of outstanding due outs at time t as Y.

Step 3. If X = 0 and Y = 0, set IP(t + 1) = IP(t) and OH(t + 1) = OH (t), then go to step 2.

Step 4. If Y = 0, go to step 5. For y = 1 to Y compute OH (t) = OH (t) – DO(t,y) (where DO(t,y) is the quantity due out for the yth outstanding due out on day t). If, for any y, OH (t) > 0, compute CWT = CWT + (t – the time of the demand that established the due out). If, for any y, OH(t) < 0, stop. Establish outstanding due outs for time t + 1 from prior due outs.

Step 5. If X = 0, go to step 2. For x = 1 to X, compute OH(t) = OH(t) – QTY(t,x) (where QTY(t,x) is the quantity demanded for the xth demand on day t), if for any x OH(t) is < 0, set it equal to 0 and establish a due out at time t + 1 for the current (can be a partial due out) and any remaining demands. For any x for which OH(t) > 0, set CWT = CWT + 1.

Step 6. For x = 1 to X, compute IP (t) = IP (t) – QTX(t,x). If IP(t) ≤ ROP(iter), establish a due in to arrive at t + RLT of quantity RO(iter) – IP(t). Go to Step 2.

Step 7. Set CWT(iter) = CWT/Total number of demands processed.

APPENDIX E

Simulation and Generation of Stockage Alternatives

This appendix describes the outputs of the DCB algorithm (shown on the right side of Figure A.1). This appendix is of most use to those who are involved in the ASL review process and need to understand the organization of the DCB outputs.

There are three main steps involved in the generation of outputs:

- **Access database macros/alternative ABFs.** The Access database is used to apply sets of constraints and produce alternative ABFs that are input to a simulation program. During this process, five alternative ASLs are developed based on investment and mobility parameters.[1]
- **Simulation.** Performance of each of these alternatives is estimated by stepping through the demands transaction-by-transaction while maintaining on-hand, due in, and due out inventory levels using the recommended RO and ROP levels. See Appendix D.
- **Predicted performance/five alternatives.** Mobility and investment information are combined with the supply performance predictions to build a decision brief to be used by local supply

[1] A macro in Access generates the five alternatives. Any other alternatives can also be developed manually from the database by writing queries, but the five alternatives (along with the current ABF) are automatically generated so that a resource-versus-performance curve can be established.

managers. Local supply managers use this information, along with their own research, to develop a recommendation to local leadership based upon a specific cost/benefit tradeoff. The brief provides analytic support for the recommendation. Local supply managers are also given RIC/NIIN level output for review/modification.

The five alternatives compare to the single set of recommended inventory levels "demand analysis output" in Figure 3.1. Any changes by local supply managers are fed back into the database. Once the final RO and ROP levels are known, the database is used to build a file with the transactions needed to update the inventory levels on the ABF. The file is then transmitted from RAND Arroyo Center to the supporting CTASC, where the transactions (which have a document identifier code of "YEB") are entered into the SARSS through a Network Router Service Request. The transactions are then processed just as though the file had been generated internally.

APPENDIX F

Modified EOQ Formula

The DCB algorithm uses a modified version of the classical economic order quantity formula.[1] The basis of the modifications is to send correct signals to the higher echelons of the supply chain and handle the transition from a DOS-based order quantity to an EOQ-based order quantity across the Army. This appendix is of interest to those with a knowledge of inventory theory and an interest in EOQ logic.

Prior to DCB, many of the items requested were not stocked. So each time the customer came to the SSA with a request, a requisition was sent from the SSA further up the supply chain. Because many of these items were low cost, there was concern that suddenly switching to an EOQ order quantity would create a surge of demand as the items were added to the ASL followed by no demands as the SSAs worked off large EOQ quantities.

The standard EOQ formula is,

$$EOQ = \mathrm{sqrt}\ (\ (2*AYDQ*OC)/(UP*HC)\ )$$

Where:

sqrt implies take the square root.

AYDQ = average yearly demand quantity for the item.

OC = marginal order cost (the Army uses $13.26).

[1] See Hadley and Whitin, op. cit.

UP = unit price of the item.

HC = marginal holding cost as a percentage of unit price (the Army uses 22 percent or 0.22).

As coded, we take the maximum integer value greater or equal to one.

EOQ = max (1, sqrt ((2*AYDQ*OC)/(UP*HC))).

The maximum function (max) rounds up all fractions less than one to one. All other fractions are rounded to the nearest integer.

The modifications to the EOQ limit the value to a multiple of the yearly demand quantity unless the yearly demand quantity results in an order value less than a preset limit. The equation is

MEOQ = int (max (min (MULT * AYDQ, EOQ)), MVO/UP + 0.5).

Where:

Int implies take the integer value (with the + 0.5 rounds to the nearest integer).

MEOQ = modified EOQ.

MULT = multiple of the yearly demand.

MVO = minimum value order.

While the OC and HC have standard values in Army policy, no such values exist for the MEOQ parameters MVO and MULT. We initially used 0.5 then increased to one and then to two for MULT. This implies that SSAs would on average replenish at least twice yearly, and then once every two years (except for cases affected by the MVO parameter; see below). For inexpensive items, this stopped the EOQ formula from computing order quantities that replenished very

infrequently in most cases.[2] Hence, demands would continue to occur in the higher echelons of the supply chain.[3]

The MVO parameter offsets a problem created by the previous parameter. Very slow moving inexpensive items could be ordered too frequently if limited to the AYDQ. Hence this parameter allows the quantity computed by the standard EOQ formula to dominate at very low demand levels. We used a value of $10 for MVO. This factor can also be computed in terms of cube to fill a bin location once assigned.

Figure F.1 is a mapping of which component of the MEOQ formula determines the order quantity at different AYDQ and UP values. In the figure, "E" implies the unmodified EOQ value determined the order quantity, "P" implies the MVO/UP parameter determined the order quantity (it was larger than MULT*AYDQ, but less than EOQ), and "D" implies MULT*AYDQ determined the order quantity. The focus in the figure is on inexpensive items and lower demand quantities, but the mapping exists for all values. The diagonal bands extend out and are the fundamental difference between the EOQ and the MEOQ.

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[2] With the order and holding costs used by the Army, the EOQ can easily be 10 years of demand or more for very inexpensive items. It is not clear these parameter values are the true marginal costs regardless of item characteristics.

[3] Many of the inexpensive items stocked under DCB used to not be on the ASL. So each time there was a customer request, a requisition was generated for the item from further up the supply chain. Typically the requisition went to an inventory control point, and then an MRO was sent to a DLA distribution center. The inventory control points also use qualification logic and track demands to determine their inventory levels. If the EOQ were left unmodified, then SSAs in the Army may have suddenly ordered large quantities of an inexpensive item. The signal to the national level would be that demand rates are increasing, increasing the RO at the national level. But then there would be no additional orders as the SSAs worked through the very large order quantities. This created the potential that the item would then be considered excess before the replenishment requisitions were initiated, and a vicious cycle would ensue. This concern would not occur if the inventory control points tracked customer requests versus SSA requisitions.

Figure F.1
Characteristics of the Modified Economic Order Quantity (MEOQ) Formula

		Average Yearly Demand Quantity (AYDQ)																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Unit Price (UP)	$0.05	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P
	$0.10	E	E	E	E	E	E	E	E	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
	$0.20	E	E	E	E	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	D
	$0.30	E	E	P	P	P	P	P	P	P	P	P	P	P	P	P	P	D	D	D	D	D	D	D	D	D
	$0.40	E	E	P	P	P	P	P	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D
	$0.50	E	P	P	P	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$0.60	E	P	P	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$0.70	E	P	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$0.80	E	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$0.90	P	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$1.00	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$1.10	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$1.20	P	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	$1.30	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E
	$1.40	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E
	$1.50	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E
	$1.60	P	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
	$1.70	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E
	$1.80	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E
	$1.90	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E
	$2.00	P	P	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E
	$2.10	P	P	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E	E
	$2.20	P	P	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E	E	E	E

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